JOURNAL
OF THE
FRANKLIN INSTITUTE
OF THE STATE OF PENNSYLVANIA,
FOR THE PROMOTION OF THE MECHANIC ARTS

VOL. CXXXVIII. SEPTEMBER, 1894. NO. 3

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THE GRAPHICS OF THE EFFICIENCIES OF THE STEAM BOILER.

BY R. H. THURSTON.

A study of the several efficiencies of the steam boiler was made by the writer some years ago, and the results published originally in a paper presented to the American Society of Mechanical Engineers. This seems to have been the first attempt to frame a practically applicable theory of the various efficiences with which the engineer has to deal in designing and constructing this class of apparatus, and the first presentation of the algebraic theory of the physical and the commercial aspects of the several problems which arise in the adaptation of the steam boiler to its location and work, having due regard to the costs and to the condition of the labor and money markets.* It was

**Transactions of the American Society of Mechanical Engineers*, April, 1882; *Journal of the Franklin Institute*, July, 1882.

then shown that there are two principal efficiencies which the designing engineer must consider in proportioning a proposed boiler plant, and two subsidiary efficiencies—perhaps, more correctly, financial measures of efficient use of capital—which he may find to assume some importance when the boiler in question is one in actual operation. These so-called efficiencies are:

(1) The efficiency of the steam boiler in the accepted sense of that phrase; the ratio of the quantity of heat stored in making steam to the amount set free in the furnace.

(2) The commercial efficiency of the operation; which efficiency measures the approximation of the utilization of capital in the given case to that highest attainable productiveness which it is the principal duty of the engineer to seek in all cases.

(3) The commercial efficiency of a given boiler plant; which, when a maximum, involves the apportioning of such an amount of work to the plant as will give highest returns in value of product.

(4) The commercial limit of efficiency with increasing demand for steam.

The first two efficiencies are of interest to the designing engineer, who has for his task the proportioning of boilers to a stated, definitely prescribed, demand for steam; the second are of importance to the proprietor who desires to increase the product of a boiler plant previously constructed for a stated power. The first two enter the problem: Given: the quantity of steam required; what size and proportions of boiler shall be supplied to produce it? The second two relate to the problem: Given: a steam plant constructed and in operation; what amount of steam can be demanded of it with maximum profit to the owner? what amount can be made without exceeding the limit cost, plus a fair business profit? In the first set of problems, the variable is the size of boiler for a stated power; in the second it is the power to be demanded from a known extent of boiler heating surface.

The first of these efficiencies is the product of a number

of what we will call "efficiency-factors," as the efficiency of heat-development by more or less complete combustion; the efficiency of heat-transfer from furnace to the water and steam in the boiler; the efficiency of transfer from boiler to engine. The second on the list above involves the first and includes the consideration of the costs of construction, placing and operating, in such manner as to determine what proportion of boiler will give the highest total return on the capital invested or continuously expended. The last two efficiencies relate to use of capital with highest results, or up to a limit set by what would be considered fair and acceptable returns. The outcome of the investigation above referred to was in brief the following:

Expenses of Operation may be reckoned under three heads:

(1) Those costs of boiler and of maintenance, reckoned as annual expenses which depend upon original magnitude of investment in boiler, accessories and necessary incidental costs, as interest or loss of profit on money invested in boiler, house, land occupied, taxes, insurance, repairs, depreciation and sinking fund for ultimate replacement, etc.; which costs are all more or less directly variable with the size of boiler adopted.

(2) Those regular annual expenses which are incurred in the operation of the boiler, as costs of fuel, transportation, firing, removal of ash, storage, if any, freight in cases of locomotive and steamship operation; and, usually, some costs attendant upon incidental operations. These costs are variable with, and may commonly be taken as proportional to, quantity of fuel consumed.

(3) Expenses which do not vary with either size of boiler, in the particular case assumed, or with quantity of fuel burned, and which may, therefore, for the problem in hand in any given case, be taken as constant.

All variable expenses may be classified in this manner into the treasurer's account of investment expenditure and returns, and the working expenses of the boiler-room, and assigned, accordingly, to classes one and two. Examples of the first class are the interest and insurance accounts; of the

second class are costs of fuel, in the furnace; of the third are chief engineer's salary, fire risks on adjacent property, etc.

Efficiencies are computed as follows:

Let

A = constant in Rankine's expression for boiler efficiency.

B = ditto.

C = cost—Class II—of fuel per annum per pound burned per hour on one square foot, *i. e.*, of one pound of fuel per hour for a working year.

D = annual investment, Class I, per square foot of heating surface of boiler.

E_1 = water-evaporating power of the fuel for unity efficiency.

E = evaporating power for computed efficiency.

F = weight of fuel burned on the square foot of grate.

S = area of heating surface per square foot of grate.

The efficiency of the steam boiler may be computed with fair approximation by employing Rankine's formula

$$E = BE_1 \div (I + AF/S) \tag{1}$$

The costs of supplying steam, as an annual charge, will be

$$P = DGS + CFG; \tag{2}$$

and the profitable work done is measured by the weight of steam made,

$$W = FGE; \tag{3}$$

while their ratio, which is made a minimum by proper adjustment of the area of heating surface, is

$$y = P \div W = (CF - DS) + EF. \tag{4}$$

Introducing the value of E, from (1), and differentiating for a minimum, we obtain

$$S = F\sqrt{\frac{AC}{D}} = F\sqrt{AR}; \tag{5}$$

in which the quantity R is the ratio of fuel costs C, to investment account D. The constant A is usually about 0·5; B is from 0·8 to unity.

The area of heating surface per pound of fuel burned is seen to vary as the square root of the working costs, inversely as the square root of the investment costs, and directly with the square root of the annual working time—this varying inversely as the preceding item, fifty per cent. more can be paid for extended heating surface, where working night and day throughout the year, than where working but ten hours a day. A doubled cost of fuel and wages would justify increase of size of boiler by one-half for a stated power, the waste of fuel consequent upon inadequate size being such as to make this double expense for boilers, and the resultant saving, a paying operation. Common values of R range between fifteen and twenty-five. Where power is required to be concentrated, and forced draught is resorted to, its value falls greatly - often to three or four—as in the locomotive and in some marine practice. The following table gives some of these values:

COMMERCIAL EFFICIENCY OF BOILERS.

RATIO OF AREAS OF HEATING AND GRATE SURFACES.

Values of S.

F	6	10	12	15	20	30	40	50
R								
25	21	35	42	52	70	105	140	175
16	17	28	34	42	56	84	112	140
9	12	21	24	32	42	63	84	105
4	8	14	16	21	28	42	56	70

From the above equations, we obtain

$$E\ max. = \frac{B\,E}{1 + \sqrt{\frac{A}{R}}} \qquad (6)$$

The following are examples, in greater detail, of the application of the above:*

* *Ibid.*; also *Manual of the Steam Engine*, vol. ii, chap. viii.

EXPENSE ON BOILER ACCOUNT AND MAXIMUM COMMERCIAL EFFICIENCY.

Cases.	Stationary.		Marine.	
	I.	*II.*	*III.*	*IV.*
Class 1 (D).	*Cornish.*	*Tubular.*	*Tubular.*	*Tubular.*
Total annual cost of boiler per unit of S	$1 50	$2 00	$3 00	$2 00
Interest	09	12	15	12
Repairs and depreciation	15	20	45	30
Rent, insurance and miscellaneous	10	07	1 00	20
Total value of D	34	38	1 60	62
Class 2 (C).				
Fuel (@ $5 for I, II, IV; $4 for III) per unit of F	7 50	7 20	12 00	2 00
Transportation and storage	1 00	1 00	10 00	1 00
Attendance (variable cost)	—	50	50	—
Total	$8 50	$9 00	$22 50	$3 00
Value of $\frac{C}{D} = R$	25	23	14	5
Value of A	0·5	0·3	0·3	0·5
Value of $\sqrt{AR}$	3·5	2·7	2·0	1·6
Value of F	8	10	16	20
Value of $F\sqrt{AR} = S$	28	27	32	32
Value of $S \div F$	3·5	2·7	2·0	1·6

The engineer thus solves the most important problem in boiler design which may be thus enunciated: To determine the commercial efficiency of a steam boiler doing a fixed amount of work; or, given all variable expenses of boiler installation, maintenance and operation, to determine what proportion of heating surface to grate surface or fuel burned will give the required amount of power at least total cost.

A second commercial problem may sometimes be presented to the engineer: A steam boiler is in place and in operation; all constant expenses are known and all variable costs of maintenance and operation are determinable. The question arises, or may arise whenever additional steam is called for: How much can be obtained from the apparatus when driven to such an extent as to yield most steam per dollar of total cost of operation? The independent variable is now the quantity of fuel burned in the boiler, and

this is, in the established equation, represented by F, the fuel burned per unit of area of grate. This problem is thus stated:

Given: All expenses, constant and variable, and the method of variation of the latter and the proportions of the boiler as actually constructed, to determine that rate of combustion which will make the commercial efficiency of the given plant a maximum.

For this case, let K represent total annual expense, which is constant,

$$\text{and let } k = \frac{K}{G}.$$

Then the total cost of maintenance will be

$$P' = k\,G + D\,G\,S + C\,F\,G, \tag{7}$$

and

$$y = \frac{P'}{W} = \frac{k + D\,S + C\,F}{E\,F}, \tag{8}$$

F being taken as the independent variable.

This becomes a minimum when

$$F_1 = \sqrt{\frac{k\,S + D\,S^2}{A\,C}}; \tag{9}$$

and

$$E\ max. = \frac{B\,E}{1 + A\sqrt{\frac{k + D\,S}{A\,C\,S}}} \tag{10}$$

The following cases illustrate this problem:

EXPENSES OF BOILER AND MAXIMUM ECONOMY OF PLANT.

	STATIONARY.		MARINE.	
Cases	*I.*	*II.*	*III.*	*IV.*
Cost of maintenance: D	$0 34	$0 58	$0 88	$0 62
Cost of operation: C	8 20	9 00	14 50	3 00
Cost of operation: K	30 00	25 00	10 50	10 00
For maximum fuel and work: F_1 .	16	13	17	21
For maximum efficiency, as before: F	8	10	16	20
$S \div F$:	1·8	2·1	1·9	1·6

Case No. 1 is that of a Cornish boiler; No. 2 that of a multitubular stationary boiler; No. 3 that of a sea-going, and No. 4 that of a yacht, as before.

It is seen that in all cases the weight of steam delivered from the boiler and the quantity of fuel burned at maximum commercial efficiency, for the case assumed, are less than where the boiler—once set and still capable of being forced to deliver more steam than originally proposed and calculated upon—is worked up to a maximum delivery per dollar of total expense.

"Maximum Commercial Efficiency of Boiler" and "Maximum Efficiency of a Given Plant" are, therefore, by no means identical conditions, and it will usually be found that when this maximum work can be put on the boiler, it might be done still more economically by a boiler specially designed, as in the first problem, to do the increased quantity of work; the conclusions from this fact being simply that economy dictates that as much steam-power as possible should be grouped into a single plant in order to diminish the proportional cost of the constant part of running expenses, *i. e.*, otherwise stated, there being given a certain necessary expenditure, invariable within certain limits with variation of size of boiler or of quantity of steam made, the larger the amount of work done without increasing this constant expense, the cheaper will the steam be made.

The larger the plant supervised by the engineer, the less the total cost per pound of steam made, other conditions of economy being unchanged.*

It will be noted that the variations above computed for F are much less than those for S; the second being compared with the first case. Also, the harder the boilers are driven, the more nearly do the solutions of the two cases approximate the same limiting values. For the cases last assumed, the quantity of fuel burned, at highest economy, to the square foot of heating surface, is seen to range from 1·5 to 3·5; in usual practice this value is observed to range, as actually obtained with customary proportions and rates

* *Ibid.*

of combustion, from two to five, and to be gradually rising, where, as in marine practice, concentration of power is becoming more and more imperative.

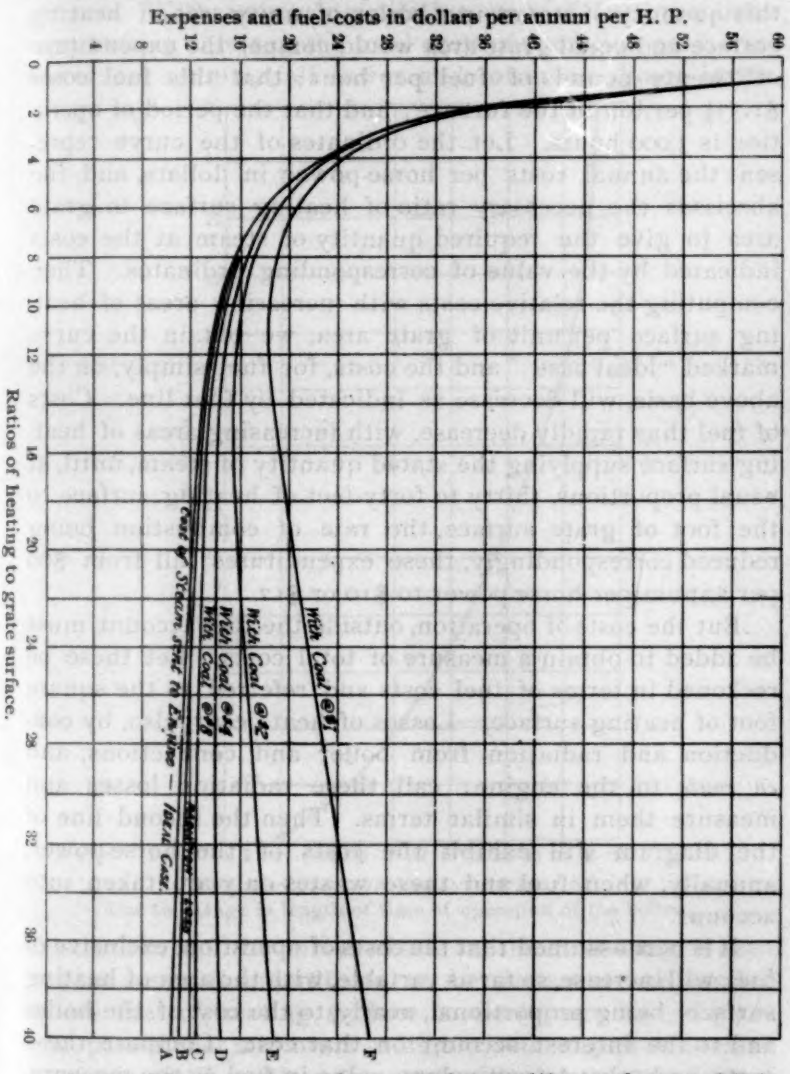

FIG. 1.—COMMERCIAL EFFICIENCY OF BOILERS.

A graphical construction may be readily made to exhibit to the eye the method of variation of costs with size of boiler. Thus, in *Fig. 1*, let it be assumed that the costs

of fuel, simply, are those of purchase, supply, and use of 90,000 pounds of steam per annum, thirty pounds per hour per horse-power of engine; that the evaporation of this quantity of steam in a boiler of unity area of heating surface and equal grate area would compel the expenditure of twenty pounds of fuel per hour; that this fuel costs $1.33⅓ per ton in the furnace; and that the period of operation is 3,000 hours. Let the ordinates of the curve represent the annual costs per horse-power in dollars, and the abscissas the necessary ratio of heating surface to grate area to give the required quantity of steam at the costs indicated by the value of corresponding ordinates. Then computing the relative costs with increasing areas of heating surface per unit of grate area, we obtain the curve marked "ideal case;" and the costs, for fuel simply, on the above basis, will decrease as indicated by that line. Costs of fuel thus rapidly decrease, with increasing areas of heating surface supplying the stated quantity of steam, until, at usual proportions, thirty to forty feet of heating surface to the foot of grate surface, the rate of combustion being reduced correspondingly, these expenditures fall from $60 per annum per horse-power to $10 or $12.

But the costs of operation, outside the fuel account, must be added to obtain a measure of total costs. Let these be reckoned in terms of fuel costs and referred to the square foot of heating surface. Losses of heat occur, also, by conduction and radiation from boiler and connections, and *en route* to the engine; call these radiation losses and measure them in similar terms. Then the second line of the diagram will exhibit the costs of the horse-power, annually, when fuel and these wastes only are taken into account.

It is here assumed that the costs of operation, exclusive of fuel, will increase, so far as variable, with the area of heating surface, being proportional, nearly, to the cost of the boiler and to the interest account on that cost. Compute these costs, and take an equivalent value in fuel as the measure, per horse-power per annum, of the quantity to be added to the ordinates of the curve for such additional costs. We

thus obtain the upper line of the diagram, on the assumption that the measure thus taken, ten per cent. on $4 per square foot of heating surface, corresponds to coal at $1 per ton. With increasing relative costs of fuel, the lines representing this, and the total costs of operation per horse-power per annum, fall lower and lower, as shown in the

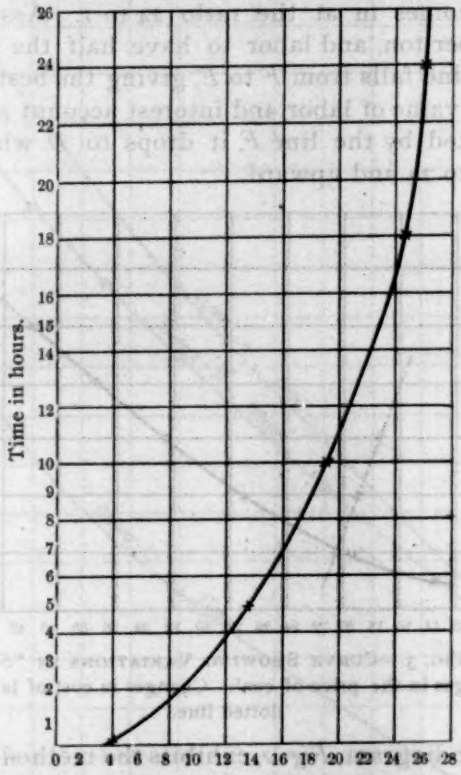

FIG. 2.—CURVE OF VARIATION OF "*S*"
Due to change in length of time of operation of the boiler.

illustration, and the curve, which, in the first case, is seen to pass a minimum ordinate at between ten and twelve square feet of heating surface to the square foot of grate area, passes that minimum at higher and higher values of that ratio, until, at $8 to $10 per ton, the best proportions of boiler are found to be far beyond the limits of usual practice.

The specially interesting fact illustrated by the diagram is the position of the best ratio of heating to grate surface in all common practice and at all usual prices of fuel and total costs. With coal at $1 per ton, we find this point which gives maximum returns for capital expended, at about 11 to 1; with coal at $2, it falls at 16; with fuel at $4 per ton, it comes in at the ratio 24 to 1. Assuming coal to cost $1 per ton, and labor to have half the value above taken, the line falls from *F* to *E*, giving the best ratio at 16; and with a value of labor and interest account at one-fourth that indicated by the line *F*, it drops to *D* while the best ratio rises to 24 and upward.

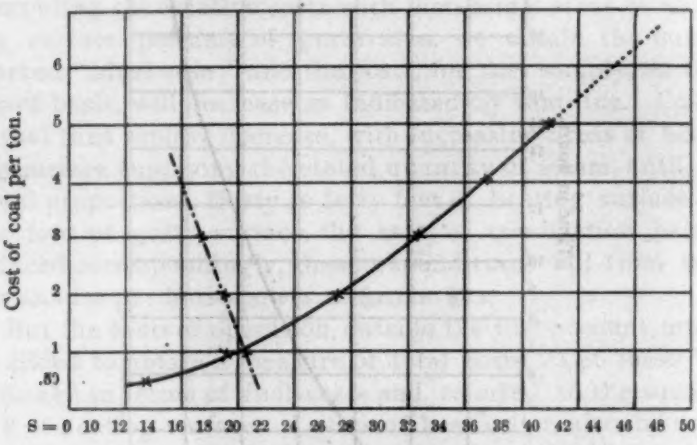

FIG. 3.—CURVE SHOWING VARIATIONS IN "*S*"
Due to changes in the price of coal. Changes in cost of labor shown by dotted line.

The next diagram, *Fig. 2*, exhibits the method of variation of the most economical proportions of boiler with change of time of working, through a range from an hour a day for the year up to continuous operation, night and day. The cost of fuel is assumed for convenience at $1 per ton and wages at $600 per year. Feed-water is taken as supplied at 185° F., and the rate of combustion as ten pounds per hour on the square foot of grate. The boiler is of 100 horse-power rated capacity, and capable, as is assumed, of supplying 3,000 pounds of steam per hour. The interest and other

investment accounts, *D*, amount to forty cents per square foot of heating surface; the fuel account, *C*, with its incidentals,

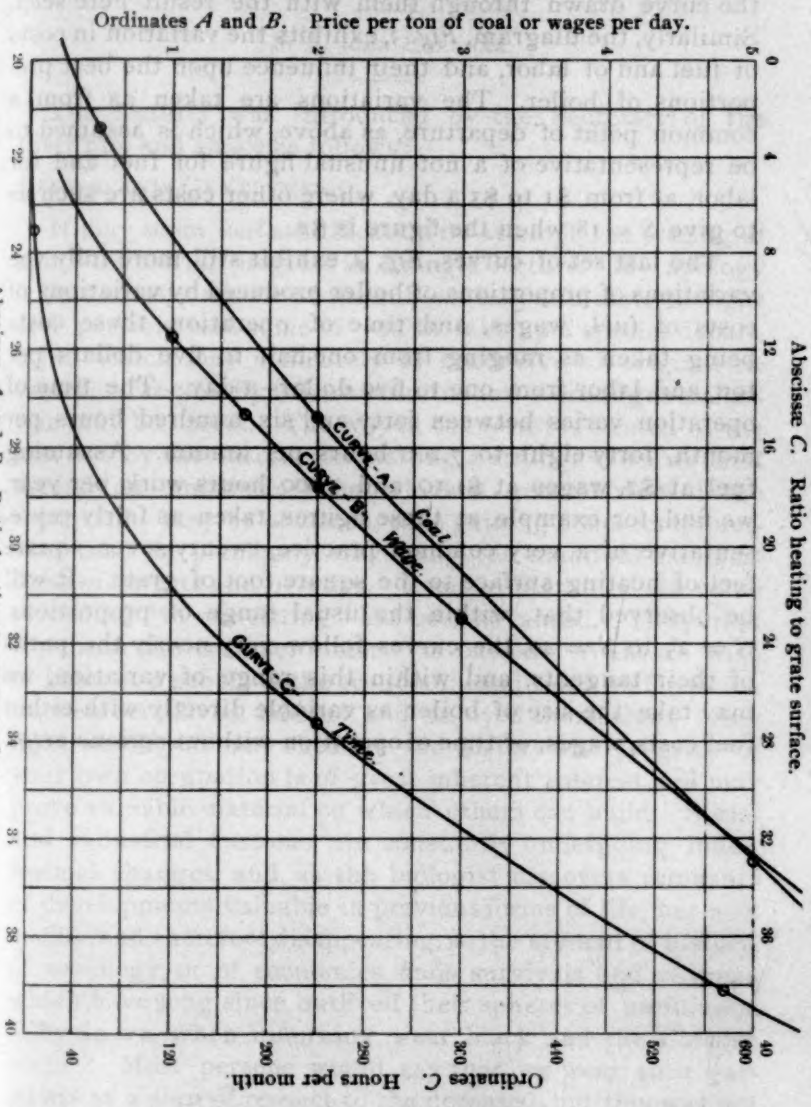
Ordinates A and B. Price per ton of coal or wages per day.
Abscissæ A and B. Ratio heating to grate surface.
Abscissæ C. Ratio heating to grate surface.
Ordinates C. Hours per month.
CURVE - A - Coal.
CURVE - B - Wages.
CURVE - C - Time.

FIG. 4.—COST AND TIME VARIATIONS.

to $15. The regular working time taken as the basis of comparison is ten hours per day. At twenty-four hours

working time per day, C becomes about $35 and D about fifty cents. Points are thus worked out in the diagram and the curve drawn through them with the result here seen. Similarly, the diagram, *Fig. 3*, exhibits the variation in costs of fuel and of labor, and their influence upon the best proportions of boiler. The variations are taken as from a common point of departure, as above, which is assumed to be representative of a not unusual figure for fuel and for labor, at from $1 to $3 a day, where other costs are such as to give $S = 18$ when the figure is $2.

The last set of curves, *Fig. 4*, exhibit still more fully the variations of proportions of boiler produced by variations of costs of fuel, wages, and time of operation, these costs being taken as ranging from one-half to five dollars per ton, and labor from one to five dollars a day. The time of operation varies between forty and six hundred hours per month, forty-eight to 7,200 hours per annum. Assuming fuel at $2, wages at $1.50, and 3,000 hours work per year, we find, for example, at these figures, taken as fairly representative of a very common practice, twenty-seven square feet of heating surface to the square foot of grate. It will be observed that, within the usual range of proportions, $S = 25$ to $S = 40$, the curves follow very nearly the paths of their tangents, and within this range of variation, we may take the size of boiler as variable directly with either fuel costs, wages, or time of operation without serious error.

THE EVOLUTION OF THE WORKSHOP.*

By C. John Hexamer.

The lecturer was introduced by the Secretary of the Institute, and spoke as follows:

Ladies and Gentlemen:

It may seem self-stultification to attempt the tracing of man's industrial progress in a single lecture. My apology is that a hasty review of the subject may stimulate thought and possibly lead some of you to take up a special department, which may ultimately be conducive of original research. Frequently, where minutiæ fail a broad generalization may be useful. The way in the forest is cleared by the axe, not by the razor. On visiting a strange town we first ascend an eminence, from which a general view of the topography may be obtained, thus gaining a clearer impression than by planlessly traversing the manifold ramifications of streets and by-ways. Even in literature the value of reading "in one sitting" has been advanced. The period of "drum and trumpet history" is passed. What we wish to know of a people is the economic conditions under which its members lived, labored and enjoyed themselves. Any light which you may shed on the history and progress of your own occupation is of great inherent interest and may prove valuable material on which others can build. Social and industrial customs are constantly undergoing infinitesimal changes, and, as the biologist discovers remnants of developments valuable in previous forms of life, but now useless and therefore disappearing, so the student of history, of sociology, or of economics, finds survivals and customs which have long since outlived their spheres of usefulness. Why do we, when mourning, wear black and the Chinese white? Most persons would say that we wear such garments as a sign of respect to the deceased, but this was not

* A lecture delivered before the Franklin Institute, December 8, 1893.

originally the case. The custom is a survival of the time when such dress was worn to indicate the "uncleanness" which was popularly associated with death and the grave. The early Aryan Nature Worshippers in Greece armed their dead warriors with a sharp sword, as they believed they would need it in the other world. When this belief died out, the custom survived in a debased form, and a little gilded sham sword was placed with the dead.

Aristotle has called man "a social (political) animal." "*A working animal*" might be a more appropriate term, for without labor and the creation of values, true happiness and social intercourse are impossible. Man was originally a "jack of all trades," necessarily forced to supply all his own wants. With the rise of his social position and the development of organization in the race his activity became more intense and its field less extensive. In other words, the higher his social position, the greater became the subdivision of labor, and the more of a specialist did be become.

When and where man first appeared on earth is a much disputed problem. Where authorities disagree by hundreds of thousands of years, it is idle for the layman to speculate. I prefer to follow Dr. Daniel G. Brinton, the eminent Philadelphia anthropologist, who is not an extremist in his views. The earliest deposit in which man's remains are found is that called the "drift," a series of gravel beds found in the valleys of the Thames, the Somme and the Manzanares. In these beds, stone tools and weapons have been discovered, lying in their original relative positions with the bones of animals long since extinct, and which could not exist in those localities under our present climatic conditions. After the warm period in which these animals lived, one of extreme cold followed, which man, however, weathered. Huge glaciers covered Scotland, Scandinavia and Switzerland; the forests of France were the haunts of Arctic quadrupeds, such as the reindeer, the white fox, etc.

Dr. Brinton estimates the period thus consumed and the time requisite for primeval man to develop and to spread over the area in which he lived, at not less than about 50,000 years; while other writers of eminence have demanded

200,000 years to explain all these changes in climate, organic life, denudation and deposition, etc.

The races of men have, largely on philological grounds, been subdivided into Aryan, Semitic and Turanian. The latter is the general receptacle into which are placed all those peoples of which we know little or nothing. The most ancient records of civilized man are probably those found in Chaldea. The most recent excavations of Layard, Loftus and Ernest de Sarzec, the French consul to Bagdad, show that other mighty and highly civilized cities existed in Chaldea before Babylon flourished. From these the culture of Babylon and of Assyria, and in all probability that of Egypt, were derived. I will not venture to speculate as to the time requisite to bring this people up to the high state of culture in which, judging from archæological excavations, they must have been almost 4,000 years before our era. The earliest paleographic records we have are the mace-heads and seals of Sargon, of Agade, dating from 3800 B. C. The writing of this people, although yet distinctly linear, assumes the wedge shape, and the art of seal-making seems to have been in advance of the sculptures of the time. These ancient Chaldeans were acquainted with most of the useful arts; they were metal-workers, sculptors, weavers, etc. The art of music had been introduced, as is evident from representations of the harp, and of men with pipes and cymbals.

Although I should not like to go as far as those who boldly declare the Chaldaic origin of Egyptian civilization, if, in fact, I have a right to express any opinion on a subject in which I am not a specialist, I believe that the Egyptians, originally a hamitic people, were largely civilized by semitic immigrants, and that their culture and racial types were greatly altered by commingling with the semitic invaders. An authority on this subject has thus well summarized the present state of our knowledge on this subject: "For the present we must be content to say that in the remote period before the pyramid age, in the fifth millenium before our era, there was a sea communication between Chaldea, Punt, Egypt and Sinai, and an interchange of the elements of

civilization. There is a convergence of the lines of origin of the two great civilizations of antiquity, but as yet their point of meeting is lost in the haze of the past."

It is, of course, exceedingly difficult to tell exactly what was the state of the people and of the workers of very ancient times. With caution, not driving analogies too far, we may learn something from the semi-barbaric tribes which we find in various states of progress at the present time. Fiske has well pointed out that the tribal forms of our American Indians have shed new light on the early tribal life of Greece and Rome. It is probable that the laborers of ancient Egypt were serfs, in condition not very different from the fellahs of the present day. Ebers relates how, when the statue of an ancient Egyptian overseer was brought to light, the native laborers at work immediately cried out: "It is our tax collector!" and it is probable that the Jews who had settled in lower Egypt were not more severely oppressed than the rest of the people. They had settled during the reign of the Hyksos, semitic invaders who ruled Egypt for a time, and when, by a national revolt, native princes were called to reign, special favors formerly granted the Jews were revoked.

In Assyria and Babylonia there seems to have been a system of slavery and of castes.

Another semitic people, the Phœnicians, were the great artisans of antiquity. They built the temple for the Jews, and were akin to them in blood and in speech. From them the Greeks first acquired the arts, as is well shown by the ancient myths of Cecrops, Danaus, Cadmus, etc. Even the Greek religion, an Aryan nature-worship, was largely influenced by them; thus Hercules was a transformed Melcarth, Aphrodite an Ashtoreth. Unfortunately, almost all records of the Phœnicians are lost, and all that we know of their great colony, Carthage, is what we have received from their implacable enemies, the Romans.

With the Greeks the ideal of beauty was born into the world. Their great maxim, "Nothing too much," guided them in everything and made them masters of absolute proportion in art, architecture and literature. Their daily

life we know comparatively well. Most of their work was carried on by slaves. In conceiving of the condition of the slaves, we must, however, disimbue our minds of the modern idea of slavery. These slaves were frequently highly cultured persons, who taught the children of their masters. Thus our word pedagogue is taken from pedagogos, originally an old slave employed to take children to school. Mahaffy tells us that the average price of a slave, calculated in our money, was $40, and that of a horse $60. The free Greek believed manual labor degrading, and the poor Athenian, rather than work, would serve on a jury and live on a few cents a day. Work was left to slaves and aliens. The ancient Greeks divided their property into two classes, the visible and the invisible. The great *entrepreneur* or speculator was honored, but bargaining was looked upon as a species of cheating, and was carried on almost exclusively by aliens. The rate of interest was 12 per cent.

Among the Romans we find a similar state of affairs, the work being left to slaves and freedmen (slaves set free). With them we find, for the first time, a sort of guilds; for the chapters, which long were looked upon as a species of our secret societies, seem to have been trade guilds. To Rome we owe the conceptions of law, order and civics. They gave us the contract, that great boon of the weak and poor, through which, by combining, they can compete, as incorporated bodies with the rich and powerful. Rome committed moral suicide. One of the Church fathers tells of a woman who danced on the grave of her twenty-sixth husband, she having been the sixteenth wife of the deceased. Ethical debasement was followed by physical weakness, and Rome died for want of men. When the Germanic tribes broke into Italy they found it an empty egg-shell, readily crushed. We must be careful not to form our ideas of ancient life from plays and novels, except those written by eminent historical authorities, and these, *en parenthèse*, are frequently not of high literary value. Thus, the people in Shakespeare's "Julius Cæsar" are not Romans and do not talk like Romans. They are the shoemakers, tailors, etc., of

the time of Elizabeth, when Shakespeare wrote. This, of course, does not detract from the high standard of the play as a literary production.

It was destined that the Teutons should infuse new blood into decrepit Rome and ultimately hand down the ancient civilization in its present form. In order to readily collect taxes the government in later Rome bound the tillers to the soil, and we can understand the evolution of serfdom only by studying these conditions. These semi-serfs were protected by the army, which was largely made up of Germanic mercenaries. The usual Teutonic tribal form was: (1) A king, duke or leader; (2) the Council of wise men or elders; and (3) the General Assembly of the people, which last has survived, in one form or another, in the make-up of the executive and legislative bodies of to-day. When the Goths had conquered Rome, they formed the fighting or protecting class, and for this protection they exacted taxes and allegiance. From this system of allegiances feudalism slowly grew. After the Germanic tribes, the Angles, Saxons and Jutes, had conquered England, they brought with them their Teutonic usages, and when later they settled in towns we find the town council a feature which is still preserved in our New England town meeting. The chief was the Reeve, and when representative government was installed, a Reeve had to be chosen for the Shire. He was called the "Shire Reeve," a term from which our word "Sheriff" is derived. The Shires of England, it should be explained, were at one time independent kingdoms. By the conquest of the Normans (a Scandinavian-Teutonic race which for a time had settled in Normandy) things were slightly changed, and a Town or Thorpe (the German Dorf) assumed this form. There was the manor, with, first, the lord of the manor, usually a Norman, the village tract of cultivated ground around it; and the commons, composed of fallow lands and woods. In parts of Germany this is still found in the modified forms of the Gemeinde Wald and Gemeinde Wiese. Thus lived nine-tenths of the people in England. By the fifteenth century the serfs had become free in England. Serfdom lingered on much longer in Ger-

many, giving rise to endless trouble, such as the terrible revolt of the peasants at Rothenburg-on-the-Tauber.

After the restoration of order, and when the general shaking-up caused by the migrations of the Teutonic races had subsided, and when walled cities had arisen to give protection to tradesmen and merchants, these classes united, for mutual protection, into guilds. These guilds in many cases became the real town governments, entering into agreements with the guilds of other cities and even with those of foreign countries. The emperors and kings, early recognizing in these guilds powerful allies against the haughty and unruly nobles of their realms, were anxious to extend to them their patronage. Thus were evolved the mighty leagues of the cities on the Rhine—the Free Cities and the Hanseatic League (with its own emporium in London at the steel yards) which could successfully cope with the most powerful princes of the time. Later the craft-guilds originated, in which various workmen of a certain trade united, such as the weavers, fullers, armorers, cutlers, bakers, and crafts which are no longer practised, such as the fletchers (makers of arrows) and bowyers (makers of bows). In London the guild of the goldsmiths became of great value to the world at large. They issued certificates on bullion deposited, and gave additional credit for such deposits, introducing thereby our present system of banking, known as the English system. The statement which is often made, that the bank of Amsterdam originated our system of banking, is erroneous. This bank issued certificates for the amount on deposit only. The guilds were true monopolies. They were beneficial, providing a common fund for the sick, for the aged, and for widows and orphans. They assisted members of their fraternity who fell behind in their contracts, and celebrated the annual feast of their patrons, for each craft had its own special patron saint. They regulated manufacture and prevented all competition, and were thus largely economic in their functions. Ben Akiba has well said, "there is nothing new under the sun," and many now make propaganda for a "new" theory, not essentially different from the one then in vogue. Every-

thing moved in prescribed ruts. Every countryman was a member of a town community. Every merchant and mechanic was a member of a guild. In some cities art guilds were formed, such as the *Meistersänger*, who carried on poetry and music by absolute rule of thumb. Of all the prodigious quantity of so-called "poetry" produced under these conditions, but a few gems by Hans Sachs now retain value. The rest is rubbish.

But the mediæval system was to disappear and the ice-bound world of custom was to be broken up by the spring-tide of revivifying thought and learning. The period known as the re-birth (renaissance) had come. Through the study of the methods of the ancients, of their mode of thinking, their philosophy, their literature and art, new literatures and new periods of art arose. The fall of the Greek Empire, in 1453, drove many Greeks into Europe, and this also had some influence on the intellectual awakening, although by no means so decisive a one as is frequently ascribed to it in text-books. The invention of gunpowder enabled the physically weak man to successfully cope with an armor-clad giant on horseback, and to destroy the walled castles of the knights. The art of printing rapidly spread the "new learning." The introduction of the compass opened a new era to navigation and exploration. Lastly, the fall of the mediæval church removed the shackles that had bound free thought. In the towns of Flanders, arts and manufactures flourished, and, under the greater security of free protected cities, gave rise to more liberal institutions and to greater freedom of speculation. The validity of the inscription on the peristyle of our World's Fair, "Ye shall know the truth, and the truth shall make you free," is borne out by history. With the increase of manufactures in Flanders, a reflex action was noticeable in England. The latter country had been a great grain-producer, but with increased remuneration for its excellent wool, which was in great demand on the other side of the channel, an extension of sheep-raising, and, *pari passu*, the enclosure of commons and the consolidation of small holdings followed. When, through subsequent oppression, many liberal Hol-

landers emigrated to England, they introduced and taught the art of weaving and working woollen goods, creating a still greater demand for large sheep farms. The villagers or small farmers were gotten rid of by ignoring the old traditional security of tenure, by confiscating commons and by raising rents. Wherever tenants failed to perform all the conditions of their leases they were ejected, and expiring leases were not renewed. Violence and the bribing of legislative and judicial bodies were also brought into play, and were then much easier than now; for even the contemporaries of Henry VIII when he wished to find a pretext for the judicial murder of Sir Thomas More, and therefore preferred charges of venality against him, were much surprised when the trial proved that the Chief Justice had never received presents from litigants, as was then a common custom.

In these various ways the small farms were depopulated. The ancient holdings and claims of the thorpes were denied, and the inhabitants of the villages were scattered to the winds by reason of the changes in the economic conditions. Those who had formerly been prosperous small farmers became laborers on large farms, others were retained as helpers on sheep farms, and only the more fortunate and intelligent became large farmers. But many found themselves members of a starving peasantry, vagabonds and sturdy beggars (although begging was by statute made a crime), and finally many became paupers and criminals in the towns. The former lords of manors became great landlords, of whom the large farmers rented their lands; and only farm laborers occupied the old villages.

In towns, the guilds were destined to be broken up. Whenever a number of persons are banded together to advance a monopoly, they are sure, fortunately for mankind, sooner or later to hang themselves in their own rope. The guilds had become very exclusive; allowing special privileges to the sons and sons-in-law of members, charging excessive entrance fees, and increasing the time of service and other requirements of apprenticeship, while the increase in the capital necessary for engaging in business made it more difficult for journeymen to become masters.

In the sixteenth century a class of capitalists, merchants, arose, known as "clothiers." These set spinners and weavers to work in the cottages of country villages, furnishing the raw material and paying a fee for the labor expended. This was the final death-knell to the guilds, the remains of which exist in our own time only as narrow aristocratic bodies. Carpenters' Hall, in our own city, is the historic remnant of a guild.

By the middle of the eighteenth century the towns had lost their supremacy in manufacturing. Cheaper living was to be had in the country, and weaving was carried on in combination with agriculture. But by 1750 a change in England had become imminent. The population of the country, which, at the time of Elizabeth, was only 5,000,000, had grown rapidly. Her colonies consumed large quantities of goods, and there was a demand for more rapid production, while capital had accumulated, and was anxiously awaiting the opportunity for investment. In 1761, the English Society of Arts offered two prizes, of fifty and twenty-five pounds respectively, for the best, and the second best, invention for spinning six threads by one person; but the devices submitted were not practical.

The *Era of Invention* was however soon to dawn upon the world. In 1764, Hargreave invented the "spinning jenny," by which first eight, then twelve, then twenty, and ultimately a hundred threads were spun at a time. The secrecy in which this invention was at first shrouded was soon divulged, and in less than a dozen years the jenny was in general use. In 1768, Arkwright gave to the world the "water frame." Crompton invented "the mule" in 1776, combining the advantages of the jenny and of the water frame. Rapid improvements in carding machinery followed. Cartwright's "power loom" was invented in 1784, and improved in 1787, and was universally in use by 1800. In 1792 our great American inventor, Josiah Whitney, gave to the world the cotton-gin. There was now a pressing need for greater and more reliable power to drive machinery. Watt improved the steam engine in 1769; and in 1785, one of the most important dates in history, the steam engine

was first used to furnish power to a cotton mill. This broke up the system then in use. Special factory buildings of greater size had to be constructed, and these were now located near fuel supplies, and where raw materials and products could be more readily handled; the details of manufacture became more complex, greater capital was requisite for a manufacturing enterprise, and its management necessitated greater executive and business ability. The prices of goods were rapidly lowered by the enormous increase in production, but the introduction of more advantageous methods of manufacture nevertheless permitted the rapid accumulation of great fortunes. The great *entrepreneurs* became a new aristocracy, that of money.

There was now a seething wave of humanity, from the country to the towns, the reflex of that which had once set in from the towns to the country. Forced by additional enclosure acts, the poorer country population swarmed to the factory towns, and England became, as has been well said, "a great industrial organization, where everything was done on a large scale and the world was her market." In this great workshop, the laboring population, having lost its hold on land, on capital, and on the direction of the enterprise, was cut adrift. The great masses of the population were mill-hands, and practically the slaves of employers. There were then no associations and trade unions, and deplorable conditions existed. Wages were low and hours extremely long; women and children were worked beyond physical endurance, and their habitations were those of squalid misery. I will not dilate on the sickening details of physical and moral debasement of "the sweating systems" of those times, when children, in order that manufacturers might procure still cheaper labor, were apprenticed from almshouses.

The world was then laboring under a most inhuman economic system. The "*laissez faire*" doctrine was carried into practice, with its appendages, the theories of the "wage fund" and of the "iron law of wages," teaching that there is in each country a certain amount of money to pay wages, and that if the population increases, there must be a cor-

responding decrease in wages until a sufficient number perish to restore wages to a living standard for the remainder.

As is so frequently the case, help was not to come from educated theorists, but from the sound common sense of the middle classes. Amidst the tremendous opposition of manufacturers and of disinterested political economists and their followers, who declared that the government had no right to interfere, the first factory act was passed in 1802. Its interference was exceedingly mild, its enactments being limited to such trivial requirements as those providing for the ventilation and whitewashing of factories, stipulating two suits of clothes annually for "bound children," and limiting the working day of these unfortunates to twelve hours. Again, the exertions of the sound-minded middle classes secured, in 1833, the appointment of a parliamentary commission, whose report was followed by an act which stipulated that no children under nine years should be employed; that those between nine and thirteen years of age should not be worked more than eight hours, and those between thirteen and eighteen not more than eleven hours each day, and that boys under twenty-one and women should not be put on night work.

Slowly the *Era of Trade Unions and Socialism* came into being. Laborers began to recognize their community of interest, and attempted to unite, but an act of 1799 made it a crime for them to combine for an increase of wages, or a decrease of working hours, or to persuade others to leave work; and it was not until 1875, after a number of previous ameliorating acts had been passed, that the last remnant of illegality was removed from such combinations. It is unnecessary for me to dwell on the phases of the struggle in our own country, the several State acts, labor commissions, etc. At present, Australia, to which we owe so many reforms, is attempting to evolve a practical system of arbitration. The weapons wherewith capital and labor have been combatting are the "strike" and the "boycott" on the one side, the "black-list" and the "lockout" on the other. These, however, are too well known to require detailed description

here. It is noticeable that both sides are becoming more moderate in their views, and that their disputes are becoming less acrimonious. Labor unions act like double-edged swords. Restricting, as they do, individual freedom of action, their members must necessarily sacrifice some of their personal freedom. But human social progress has been in the same direction. As citizens of a State and of a community, each of us gives up certain individual rights for the general welfare. We are slowly recognizing the equity of State interference, notwithstanding the trumpet blasts of such ingenious theorists as Herbert Spencer.

Brushing aside feudal aristocracy, which is practically effete, though still lingering on in parts of Europe, and the adoration of American heiresses, we may, for practical purposes, divide humanity into three classes: the capitalist or money-lender, who receives interest; those who build and operate mills, keep stores, manage, receive profits, etc.; and those who do daily work and receive wages. It has been attempted to unite these functions by a system of co-operation, as in the experiment of the Rochdale Pioneers in 1844, when twenty-eight workmen each subscribed $5, agreeing to buy only at the co-operative store. In 1882, there were 1,268 such stores with 650,000 members, and it is stated, on reliable authority, that in Northwestern England, one-fourth of the population buys its supplies from co-operative stores. Another experiment was that of the Minneapolis coopers. In 1874, sixteen of these coopers contributed $15 each, and established a shop of their own, dividing the profits. Leclaire, a Paris painter, in 1842 began the system of sharing profits with employés, who had been long in his employ. The Oxford Building Association was an attempt to stimulate thrift, and extended its example, in 1831, to the United States, and the plan has proved astonishingly successful in our city of homes. Great competition has also called into being combinations of manufacturers, known as "trusts."

In recapitulating these successive steps of combinations, accompanied by limitations of the personal rights of individuals, we cannot forbear asking the question: Are we drifting toward socialism? This is a proposal to abolish

competition and individualism, substituting for them some form of government or social control over land, capital, management, distribution and labor. It opposes competition, rent for land, interest on capital, computed profits and the individualistic ideal of society. In other words, each individual works for the community instead of for himself, and each one receives from the community and not from other individuals or corporations. Wherever the system has been tried practically it has proved a failure. In early colonial times in this country, we find it wrought starvation. In Russia the great famines are the direct outcome of the communistic system of the Mir.

Louis Blanc is the originator of that form of modern socialism which is opposed to the radical measures formerly advocated, and proposes the utilization of present governments to commence reforms, and thus gradually to lead to socialism. (Another form emanating from the brains of poets and visionaries has given rise to what is known as Nationalism.)

It would be idle to speculate on what we shall ultimately reach, but I think it is safe to say that we are tending toward government ownership of railroads, the telegraph and telephone lines and all municipal necessities. In Germany, a great statesman, Bismarck, has introduced compulsory insurance.

After tracing thus rapidly human industrial progress from the most ancient times to the present, we cannot more aptly close than by asking and attempting to answer the question: *What is the present status of the evolution of the workshop?* Competition has broken down in many lines of practical business, and trust combinations of all sorts flourish, notwithstanding the opposition of statutes, courts and public opinion. Even violent measures, such as reductions of tariff, free trade, etc., prove of no avail, as powerful trusts are better able to successfully meet foreign competition than small business concerns fighting single-handed. The *raison d'être* of trades unions is now generally recognized, and they are encouraged. Co-operative efforts have been in part successful and are still on trial; and factory laws have been enacted in all civilized countries.

We have no reason to fear the future. Extremists may prove temporarily obnoxious, but will not prevail in the end. They may, indeed, do good, as the happy mean is found between the extreme pendulum-swings of human thought. These problems will be solved, as all human progress has been accomplished, by infinitesimal changes directed by economic conditions. Nor need we dread the increase of population, for history and sound economics clearly teach us that such fear is groundless, and have established the grand ethical axiom, that bed-rock of human experience on which we can safely build, that in the end right and truth will prevail.

A THEORY OF THE ACTUAL EARTH PRESSURE AND ITS APPLICATION TO FOUR PARTICULAR CASES.

By P. Vedel, C.E., M. West. Soc. Eng.

[*Concluded from p. 148.*]

In these expressions θ everywhere is to be taken positive or negative according as φ is positive or negative.

Is $R = o$, *i. e.*, the cylinder an infinitely thin rod, then (11) gives

$$F = \begin{cases} o \\ \frac{1}{2}\pi\gamma H^3 \dfrac{\cot.^2\beta.\ \sin(\beta - \varphi)}{\cos(\beta - \varphi - \varphi')} \end{cases}$$

according as the earth is

$$\begin{cases} \text{inside} \\ \text{outside} \end{cases}$$

the cylinder. For the first case (13) gives $\beta = 90°$. For the latter case (12) gives

$$\cot\beta = \tfrac{1}{2}\cot\varphi.\frac{\sin\theta\,(1 - 4\sin\theta)}{(1 + \sin\theta)(1 - 2\sin\theta)}$$

as an approximation, whereas by returning to (8) we find the exact solution

$$\cot \beta = \frac{1 - 4 \sin^2 \theta \pm \sqrt{1 + 8 \sin^2 \theta}}{4 \cos^2 \theta \operatorname{tg} \varphi}$$

This value of $\cot \beta$, therefore, will make F a maximum or minimum, or, by (11),

$$F \frac{max.}{min.} = \frac{\pi \gamma H^3 \cos^2 \varphi'}{24 \sin \varphi . \cos^3 (\varphi + \varphi')} [1 - 20 \sin^2 \theta - 8 \sin^4 \theta \pm (1 + 8 \sin^2 \theta)^{\frac{3}{2}}] \quad (14)$$

the upper sign corresponding to φ positive and the lower to φ negative.

The four particular cases enunciated above must now be considered separately. In the first case, when the bottom sinks a little, a right circular cone or frustum of a cone of earth described over its circumference will follow it, and the balance of the earth, retained by the wall friction, will slide down along the cylindrical surface and, relatively, upwards along the conical surface. Hence, φ is negative, φ' positive, or the pressure on the cylinder is what we have called passive-active.

In the second case, when the bottom is lifted a little, a right circular cone or a frustum of a cone of earth is lifted with it, and the earth which has been retained by the wall friction will also be lifted, sliding up along the cylindrical surface and, relatively, down along the conical surface. Consequently φ is positive, φ' negative, or the pressure on the cylinder is what above was called active-passive.

In the third case, when the cylinder is pushed down a little, the surrounding earth contained between the cylindrical surface and a frustum of a right cone described over the bottom and with its apex turned downwards will be lifted, sliding upwards along the cylindrical and conical surfaces. Hence φ is negative, as is φ' also. The pressure on the cylinder therefore is passive.

In the fourth case, finally, when the cylinder is pulled up a little, the surrounding earth contained between the cylin-

drical and the truncated conical surface will slide downwards along both surfaces. Hence, φ is positive, as is φ' also, and the pressure on the cylinder is active.

All possible kinds of earth pressure are, therefore, represented by these four cases.

Returning now particularly to the first of them, we have by (11) the weight, W, carried by the bottom:

$$W = \pi\gamma R^2 H - F = \pi\gamma R H [R - CH(1 - \frac{H}{3R} cot.\beta + A)] \quad (15)$$

where

$$C = \frac{cot\ \beta.\ sin\ (\beta + \varphi)}{cos\ (\beta + \varphi - \varphi')}$$

and A is the same as above. The maximum of weight, W, which may have to be carried, will correspond to a minimum of F or the value of β determined by (12) or (13).

For a given constant value of β, W will from O, corresponding to $H = o$, increase with H until for

$$H = R\ tg\ \beta\left(1 - \sqrt{1 - \frac{1}{C\ tg\ \beta}}\right)$$

if $C\ tg\ \beta > 1$, it reaches a maximum

$$W = \tfrac{1}{3}\pi\gamma R^3\ tg\ \beta\,[1 + 2\,(1 - C\ tg\ \beta)\,(1 - \sqrt{1 - \frac{1}{C\ tg\ \beta}})].$$

It will then decrease until for $H = R\ tg\ \beta$ it is:

$$W = \pi\gamma R^3\ tg\ \beta\,(1 - \tfrac{2}{3} C\ tg\ \beta).$$

For $H > R\ tg\ \beta$ will A be a positive quantity and

$$W = \pi\gamma R^2 (H - C H\ tg\ \beta + \frac{C R}{3} tg^2\ \beta)$$

which, if $C\ tg\ \beta > 1$, will decrease indefinitely until for $H = \infty$ it is $W = -\infty$. If, on the contrary, $C\ tg\ \beta < 1$, then W will have no maximum, but increases continually when H increases from $H = o$ to $H = R\ tg\ \beta$, and from $H = R\ tg\ \beta$ to $H = \infty$, when $W = \infty$.

Theoretically, therefore, the weight on the bottom can decrease to nothing or even to a negative quantity, which

means that a load could rest on the surface of the ground without exerting any pressure on the bottom.

Differentiating equation (15), denoting by $\pm \pi \gamma x^2$ the ratio of variation,

$$\frac{d W}{d H}$$

and transforming for $H < R\ tg\ \beta$ to

$$C (H - R\ tg\ \beta)^2 \mp x^2\ tg\ \beta = R^2\ tg\ \beta\ (C\ tg\ \beta - 1) \quad (16)$$

and for $H > R\ tg\ \beta$ to

$$\pm x^2 = R^2\ (C\ tg\ \beta - 1) \quad (17)$$

we find the weight carried by the bottom represented by an earth body described as follows: If $C\ tg\ \beta > 1$ it will for values of

$$H < R\ tg\ \beta \left(1 - \sqrt{1 - \frac{1}{C\ tg\ \beta}}\right)$$

be the volume intercepted between the bottom and the upper surface of the earth of a body of revolution formed by revolving the lower half of the hyperbola (16), taken with its upper sign, around the axis of the vessel;

for $$H > R\ tg\ \beta \left(1 - \sqrt{1 - \frac{1}{C\ tg\ \beta}}\right)$$

but $< R\ tg\ \beta$ it is the whole volume above the bottom of the lower half of the hyperboloid less a volume intercepted by the upper surface of the earth of an ellipsoid, of revolution formed by revolving the ellipse (16), taken with its lower sign, around the axis of the vessel; for $H > R\ tg\ \beta$ it is the volume above the bottom of the lower half of the hyperboloid less the half of the ellipsoid and less a volume intercepted of the right vertical cylinder (17), taken with the upper sign, between the upper surface of the earth and a horizontal plane the distance of which from the bottom is $R\ tg\ \beta$. If, on the contrary, $C\ tg\ \beta < 1$ it will for $H < R\ tg\ \beta$ be the volume intercepted between the bottom and the upper surface by a body of revolution formed by revolving the lower half of the hyperbola (16), taken with its upper

sign, around the axis of the vessel, which is the imaginary axis of the hyperbola; whereas for $H > R\ tg\ \beta$ it is the volume above the bottom of the lower half of the hyperboloid plus a volume intercepted of the right vertical cylinder (17), taken with the lower sign, between the upper surface of the earth and a horizontal plane, the distance of which from the bottom is $R\ tg\ \beta$. If, particularly, $C\ tg\ \beta = 1$ the weight will for all values of $H > R\ tg\ \beta$ be represented by a cone described over the circumference of the bottom with a height $H = R\ tg\ \beta$, and for $H < R\ tg\ \beta$ by a frustum of this cone.

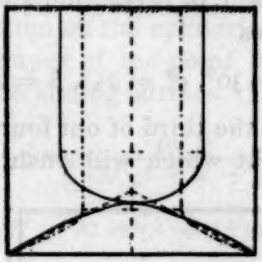

FIG. 2.

The annexed diagram, *Fig.* 2, represents the three cases for $\varphi = 30°$, $\varphi' = 25°$ and β either 40°, 27° 30′, or 20°.

In the second of the four considered problems the force to be exerted on the bottom is by (11):

$$W = \pi\gamma R^2 H + F = \pi\gamma R H [R + C H (1 - \frac{H}{3R} cot\ \beta + A)] \quad (18)$$

where $$C = \frac{cot\ \beta\ sin\ (\beta - \varphi)}{cos\ (\beta - \varphi + \varphi')}$$

The maximum force will correspond to a maximum of F or the value of β determined by (12) or (13). For a given constant value of β, W will from O, corresponding to $H = o$, increase with H until for $H = R\ tg\ \beta$ it is:

$$W = \pi\gamma R^3\ tg\ \beta\ (1 + \tfrac{2}{3} C\ tg\ \beta)$$

and from there indefinitely until for $H = \infty$ it is $W = \infty$.

Differentiating equation (18), denoting by $+ \pi \gamma x^2$ the ratio of variation

$$\frac{dW}{dH}$$

and transforming for $H < R\ tg\ \beta$ to

$$C(H - R\ tg\ \beta)^2 + x^2\ tg\ \beta = R^2\ tg\ \beta\ (C\ tg\ \beta + 1) \text{ and } (19)$$

for $H > R\ tg\ \beta$ to

$$x^2 = R^2\ (C\ tg\ \beta + 1) \qquad (20)$$

we find the weight geometrically represented, as above, by a part of an ellipsoid of revolution and a cylinder. *Fig. 3* corresponds to values

$$\varphi = 30°,\ \varphi' = 25°,\ \beta = 40°$$

Considering next the third of our four problems, it is evident that the weight which will push the cylinder down

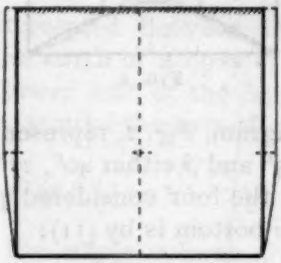

FIG. 3.

must equal the friction on the cylindrical surface plus the counter-pressure of the earth against the bottom. But it is difficult to ascertain how great this latter is. A merely vertical pressure will give the earth only a very slight tendency to move out to the sides, as we know from the experiment with U-shaped glasses, in the horizontal branch of which sand filled in one of the vertical branches will hardly advance any. And escape the earth must, for its compressibility is only very limited; in fact, a system of loose particles without friction or cohesion will, as proved experimentally by Reynolds (*Nature*, vol. xxxiii, 1886), by itself assume its greatest density or least volume, and hence

expand by any rearrangement of the particles caused by pressure or otherwise. If a pointed pile is being driven, an earth body intercepted around the conical point by another cone with the same apex will slide upwards along the surfaces of the two cones. The cylindrical part of the pile will press this earth body outward, and the resistance of the surrounding earth will cause it to move upwards. Thus the whole earth body around the cylindrical surface of the pile, limited by the truncated conical sliding surface down to the depth of the apex of the point, will be lifted a distance, dy, determined by the volume of earth, $\pi R^2 dz$, driven out by the pile going down a distance, dz. W being the weight on the pile, F the friction on the cylindrical surface, $H + h$ the depth down to the apex of the point, β, as before, the angle of inclination of the sliding surface, then we shall have

$$W dz = F dz + \tfrac{1}{3} \pi \gamma \frac{\cos \varphi'}{\cos (\beta + \varphi + \varphi')} (H + h)^2 \cot \beta$$

$$[(H + h) \cot \beta + 3R] dy$$

where

$$\pi (H + h) \cot \beta [(H + h) \cot \beta + 2R] dy = \pi R^2 dz$$

Hence

$$W = F + \tfrac{1}{3} \pi \gamma \frac{\cos \varphi'}{\cos (\beta + \varphi + \varphi')} R^2 (H + h)$$

$$\left(1 + \frac{R}{(H + h) \cot \beta + 2R}\right)$$

When the pile is not pointed, as when we consider our cylindrical vessel, it may be supposed that the earth itself forms an earth point or earth cone under the bottom, and that this point then goes down ahead of the vessel pushing the other earth out to the sides.* If the vertical pressure shall make the earth slide upwards along the surface of this cone, the angle of inclination of its generatrices must, at least, equal the angle of friction or $h = R \, tg \, \varphi$. This angle

* This supposition would agree well with the experience that piles with blunt ends are often driven quite as readily as pointed ones.

of friction may, on account of the compression, be somewhat greater than elsewhere in the earth; but as these considerations lead, anyhow, only to approximations, we may take it the same as φ.

Representing now, approximately, the friction along the earth point by the friction on an additional height, h, of the cylindrical surface, we have by (11)

$$W = \frac{\pi\,\gamma}{3\,\cos.\,(\beta+\varphi+\varphi')}\,R\,(H+R\,tg\,\varphi)\Big[(H+$$

$$R\,tg\,\varphi)\,cot\,\beta\,sin\,(\beta+\varphi)\,(3+\frac{H+R\,tg\,\varphi}{R}\,cot\,\beta)+$$

$$R\,cos\,\varphi'\,\Big(1+\frac{R}{(H+R\,tg\,\varphi)\,cot\,\beta+2\,R}\Big)\Big] \qquad (21)$$

which, when the radius of the cylinder is sufficiently small compared with its length so that terms with

$$\left(\frac{R}{H}\right)^2$$

may be neglected, reduces itself to

$$W = \pi\,\gamma\,H^2\,\frac{cot^2\,\beta.\,sin\,(\beta+\varphi)}{cos\,(\beta+\varphi+\varphi')}\,[\tfrac{1}{3}\,H+R\,(tg\,\beta+tg\,\varphi)] \qquad (22)$$

If the cylinder is infinitely long or very thin in proportion to its length, so that

$$\frac{R}{H}=o$$

approximately, then this expression is reduced to

$$W = \tfrac{1}{3}\,\pi\,\gamma\,H^3\,\frac{cot^2\,\beta.\,sin\,(\beta+\varphi)}{cos\,(\beta+\varphi+\varphi')} \qquad (23)$$

Differentiating equation (22) and denoting by

$$\pi\,\gamma\,(x^2-R^2)$$

the ratio of variation

$$\frac{d\,W}{d\,H}$$

we have

$$C'\,[H+R\,(tg\,\beta+tg\,\varphi)\,]^3-x^2=R^2[C'\,(tg\,\beta+tg\,\varphi)^2-1] \qquad (24)$$

where

$$C' = \frac{cot^2 \beta . \sin (\beta + \varphi)}{\cos (\beta + \varphi + \varphi')}$$

Graphically, therefore, the pressure to be exerted on the long and thin cylindrical vessel is represented by the weight of an earth volume intercepted below the upper surface of the earth between the cylindrical surface of the vessel and the hyperboloid of revolution produced by revolving the

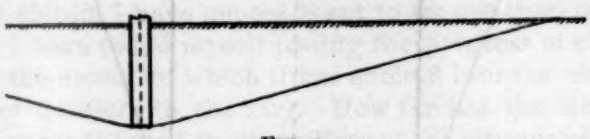

FIG. 4.

hyperbola (24). *Fig. 4* refers to this case for values $\varphi = 30°$, $\varphi' = 25°$ and $\beta = 20°$.

In the last of the four problems considered, the pull to be exerted on the cylinder will be, by (11),

$$F = \pi \gamma C R H^2 (1 + \frac{H}{3R} cot \beta) \qquad (25)$$

where

$$C = \frac{cot . \beta . \sin (\beta - \varphi)}{\cos (\beta - \varphi - \varphi')}$$

Differentiating, denoting by

$$\pi \gamma (x^2 - R^2)$$

the ratio of variation

$$\frac{d F}{d H}$$

we have

$$C (H + R \, tg \, \beta)^2 - x^2 \, tg \, \beta = R^2 \, tg \, \beta (C \, tg \, \beta - 1) \qquad (26)$$

Hence, the pull on the vessel is graphically represented by the weight of an earth body intercepted between the upper surface and the bottom of the vessel and between its cylindrical surface and the hyperboloid of revolution produced by rotating the hyperbola (26). *Fig. 5* refers to this case for values $\varphi = 30°$, $\varphi' = 25°$, $\beta = 40°$.

In what precedes, the angle, β, of the sliding plane or conical frustum has been considered an indeterminate quantity, as, in fact, it can take any value, provided only that it makes the pressure positive. The assumption that the actual sliding surface should correspond to a maximum pressure is totally unwarranted. That, on the contrary, it should correspond to a minimum resistance, as claimed by

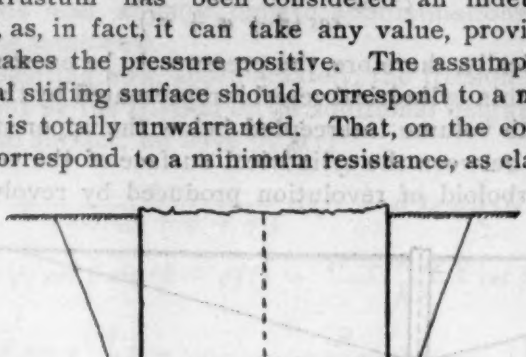

FIG. 5.

Moseley's principle of least resistance, is also unwarranted, at least in earth with cohesion. That the earth wedge will actually slide as supposed, may not always occur. Values of β which make the pressures negative would indicate that the suppositions do not hold good. The cohesive force in the earth must also influence the results, as when, for instance, in pile-pulling, the earth wedge may be lifted a little with the pile, thus sliding upwards.

ELECTRICITY IN THE MODERN CITY.*

BY THOMAS COMMERFORD MARTIN.

A few months ago, in urging the technological needs of the Western metropolis, a Chicago orator asserted that his wonderful city was the creation of engineers. I could not but feel that he was unmindful of the work done by the farmer and the pork-packer; yet so far as the visible, material city is concerned, with its lofty buildings, ramifying

* Abstract of lecture delivered before the Franklin Institute.

railroads, beautiful parks and other accessories of civilization, his remark was broadly true.

Indeed, it would be reasonable to maintain that the modern city comes nearest to the ideal when it best expresses the aspirations and achievements of modern engineering; with the corollary that a city is not modern whose inhabitants do not enjoy all that can now be had in improved sanitation, rapid transit, intercommunication, water supply, lighting and domestic conveniences.

The dictum I have quoted is apt to set one thinking, and of late I have found myself testing the progress of electricity by the extent to which it has entered into the environment of dwellers in the city. How far has the electrical engineer contributed to the welfare of the citizens of Philadelphia, for example, or in what degree might they benefit by his work if they chose? The concrete answer to a direct question of that kind will be useful and instructive. It is likely to embrace all the modern electrical arts, for, outside of meteorological observations, electricity has thus far done little good to rural peoples—their "good time," electrically, is coming. I might almost say that it is largely due to the development of the modern city that the electrical inventions of the present century have been so successful. We do not realize as we should, that the electrical arts are all of late and recent maturity. The *word* electricity is of remote and dim origin, coined perchance by an observant artisan on the shores of the Ægean, as he strung together, in the violet twilight, a necklace of amber beads, and polishing them softly, noted their quick, responsive gleam. The *art* electricity, as the name of this Institute reminds me, dates from the authentic yesterday; its forefathers were among those of our young Republic, and it was not until the present decade that one of your own citizens and members, Prof. E. J. Houston, gave precision for the first time to its nomenclature and phraseology in the English tongue.

The truth is that the utilization of electricity had to await many other refinements in the things of this life. It is, in a sense, the most feminine of all the great natural agencies that have been employed from age to age by the

human race to promote its convenience and happiness. It is the agency that most dispenses with brute force, and, whether in the telegraph, the telephone, the electric light or the electric motor, depends rather upon brain than upon brawn for its successful use. It yields us purer, sweeter subtler, gentler service than any of its predecessors in the field of illumination, heat and power have afforded us; and it cannot but be that this rarer delicacy will elevate all who enjoy it, taking us one step further from the crude, the raw and the barbaric. You know as well as I how deeply this idea has already penetrated the popular consciousness. The manner in which the leaders of public thought, or those who seek to mould public opinion, direct attention to electricity, is very striking. In reality, some of their suggestions and nostrums are as curious as those of the quacks who recommend electricity as a panacea for physical ills. Edward Bellamy, in "Looking Backward," gives a prominent role to electricity as a prime agent in his Gradgrind, workaday millennium. August Bebel, the celebrated German socialist, in his book on "Woman," asserts mysteriously that electric power is to take the first place in wiping out the "bourgeois world," clearing the world for the socialized community, and "contributing enormously to the amelioration of human conditions of existence." I, for one, shall be contented with something far short of either dream—happy, if, thanks to electricity, I may loaf and invite my soul once in a while, conscious that I am lazy for the mere selfish pleasure of it; and grateful, if, on the other hand, the extended use of electric power in mending human conditions of existence will come to the rescue of my wife by simply settling the servant girl question, and by abolishing stairs.

Now that is what "Electricity in the Modern City" means, when the argument is summed up; and all that we need is more of it for everybody. If we have electrical communication of intelligence, we save time. If we have electric light, we gain in health. If we have electric travel, we secure more leisure. If we have electric power, housework and any other work can be done with less effort. These, then, are things to strive for, and to use our influence

in promoting. Such aims and ends are the very ones for which this noble Institute was founded; this promise is the breath of hope through all its departments and all its plans for the future. The electrician can only be useful and successful in so far as he plants himself squarely in front of the social, economic and mechanical problems of the age, and brings his new art to bear on their solution.

One or two branches of my subject have become hackneyed from every-day familiarity through many years, and yet hackneyed only in a very limited sense. We all talk about the telegraph as though it were something of such terrific importance to us that nothing short of a big Government monopoly would give us all of it that we want. The bitter complaint of a friend of mine up-town in New York, that the nearest telegraph office to his house was three blocks away, set me investigating. On inquiry, I found that the local Western Union offices in New York city exchanged among themselves the wonderful total of 700,000 messages last year, or, even upon the basis of Mr. Porter's belittling census, barely one per year for every two inhabitants. The average for the whole United States is about one message per year per head. The local tariff of twenty cents per message can hardly be regarded as severe, since it about equals the car-fares that would be paid if one carried one's own message and returned; so that as regards the inner social life of a modern city the telegraph is not the vital necessity it has become between points widely apart. The statistics from Europe, where social telegrams, among denser populations, are more numerous, bear out this idea, and I do not know that we shall see ever much of a change. Mr. Wanamaker has shrewdly suggested making post-offices a receiving place for telegrams, but I doubt seriously whether that would markedly stimulate local telegraph business. In fact, telegraphing is not a universal boon to individual citizens. The telegraph ratios, under our free institutions, with more or less of private competition, vary very slightly from those of monarchical Europe with Government systems, so that we may infer from them that there are strict limitations on the social use of the

telegraph wires. Happy the nation, it is said, that is not making history; happy, say I, the countryman who is under no necessity to send or receive a telegram.

Moreover, there are two other electrical agencies, which, by their superior utility, act as a great check upon the local telegraph service, namely, the district messenger and the telephone. Both of these forms of communication are important. I am not among those who believe the district messenger boy to have been created for the sole benefit of the alleged comic paper. The slowness of the messenger boy has become as tiresome a joke as the extortion of the plumber, or the sleepiness of the Philadelphian; and we all know how foolish and empty those witticisms are. It is very easy to find out what the average district messenger boy accomplishes with the help of the electric system that brings his services into play. In New York, the messenger business of the district telegraph companies requires the services of 1,200 boys, and the number of errands performed by those boys last year was 2,600,000, or not less than six a day every day in the year, rain or shine, well or sick, Sundays and holidays. If you think that is not good work, apply the same average to your own office boy, and see where he comes out. Please remember these figures when the little chap in uniform comes around to see you at New Year.

The telephone is preëminently an instrument for local use. Its special utility is derived from the fact that it is practically instantaneous, affording usually an immediate response to the message. Besides, it is absurdly cheap to anyone who has a real necessity for such quick intercommunication. The telephone exchange in this city, over which my friend Dr. Plush so ably presides, handles daily nearly 30,000 telephonic connections. That costs each subscriber less than five cents per talk; while each subscriber has also the opportunity of reaching out to New York, Washington, Baltimore, Boston, Pittsburgh, Buffalo, and even Chicago. Are there any in my audience who will say that their talk over the telephone each time they use it is not worth five cents? Obviously, the telegraph in the city

is under serious disadvantages from competition, and I do not see how it can reduce its charges to an equality with those of the telephone, for, cheap as the telephone is, there is a possibility that, with improvements in methods, the running out of patents with royalties, and the increased use, telephonic service may gradually become cheaper. Last year, I may add, the urban population of this country sent 500,000,000 telephone messages, or ten times as many uses of the telephone as of the telegraph.

I think we must all look forward to the time in the near future, when we can have the telephone in our homes, in our hotels, and for separate office use. In my own office in New York City, our business manager has worked out and applied an ingenious telephone system, by means of which, eight different departments are connected together without the aid or intervention of a switchboard, or a "hello girl." On each desk stands a portable telephone set, and all that is needed in beginning a conversation with anybody, is to press a small plug in the proper hole in a little annunciator box. I have thus talked with three of our clerks in a single minute. Evidently here is a great gain in the dispatch of affairs in a busy office, a great saving of time, and a great reduction of running about.

As to the saving of time effected by the telephone, as well as the economy of labor, I may point out that on the basis of six messages per day to the messenger boy—the present average—Philadelphia would need 5,000 more district boys than she now boasts of, to carry one way her messages now sent by telephone. While I do not abate a whit of my advocacy and praise of the boy, I think we all prefer the telephone.

There are two incidental uses of the telegraph that closely affect city welfare, namely, the fire-alarm system and the police-patrol system. Both of these are essential elements to-day in city safety and welfare, and the former is well established. In 1890, for example, fifty miscellaneous cities in this country had no fewer than 8,400 fire-alarm boxes in use by their fire departments. It is needless to point out that this ability to give a prompt alarm does

much to keep down the loss from fire, which appears to run about $2.25 per head in cities of over 100,000 inhabitants and which would be much larger if there were greater delay. Many of our buildings now have automatic fire-alarm systems, but I look forward to the time in the near future when city ordinances will compel every large building, no matter how "fire-proof," to connect itself with the nearest fire station, either directly or through the telephone exchange. As to the police patrol system, I can only say that in nearly all our large cities its application is still very defective and inadequate. There are no statistics on the subject, and much of the work has been tentative. It must be evident that a system under which every policeman is put in direct touch with his headquarters, at his own will, or by call from his chief, means an enormous increase in the efficiency of the force. In our largest cities to-day, there are about fourteen patrolmen to the square mile, giving each man about one and one-quarter miles of street to guard. With an effective communicating system, known by evildoers to be readily available by the officer, the attempts at crime and the escapes would be much less numerous. In cities of less than 100,000 inhabitants, where there are barely four patrolmen to the square mile, such a system of bringing reserves quickly to any point of need is even more greatly to be desired and recommended. These are days when shrill whistling and three taps on the sidewalk are sadly primitive means of ensuring the public peace. The burglar alarm and the police patrol are none too good as an offset to the scientific cracksman and the drunken tough.

Probably that branch of applied electricity which of late years has made the deepest impression in our cities, is electric lighting. I do not expect any one will challenge the statement when I say that the electric light has been one of the greatest boons of modern invention. I said "boons" not "booms," for as a matter of fact the progress in the use of the electric light has been amazingly slow. There has been a great development of arc lighting for the streets, and we now see very little done in the way

of erecting gas or oil lamps in city thoroughfares. Investigation of a group of 278 cities, ranging in population from 10,000 to 100,000 and with an aggregate of 7,000,000 inhabitants, in 1890, showed more electric street lights in use than gas lights; and the tendency everywhere is steadily towards the complete supercession of gas. But, after all, such an employment of electricity is a very small one. There will be more arc lights in the single Manufactures and Liberal Arts Building at the World's Fair than the city of Philadelphia now pays for on all its streets. Hence, I do not think we have too many of them yet. I must confess to an humble opinion that they are an element of beauty in the city, shining as they do so whitely and insistently, like Shelley's "radiant sister of the day," and recalling, every time one looks down a long stretch of them, that striking passage in the old English poet, Marlowe:

> **"For every street like to a firmanent**
> **Glistened with brea hing stars."**

Perchance some of you may not find in them the appeal to the imagination that I do, but you will agree with me that their utilitarian side is also a strong one. That is the view taken of them by most civic authorities, who hold the ordinary arc light to be as good as a policeman. Sometimes it is equal to two.

It has been estimated that, of the total candle-power which can and which should replace gas-lighting, about five per cent. will be furnished by arc lights. The inference therefore is, that the incandescent light has a larger part to play than the arc in city life. This is exactly the case; and it is only when we come to examine the figures that we realize how little has been done towards the universal adoption of electricity for our homes and offices. The dynamo capacity in the United States to-day for supplying current to incandescent lamps is about 5,000,000 lights, and the number of lights wired up is about 7,000,000 or 8,000,000. The production of incandescent lamps runs about 25,000 to 30,000 a working-day all the year round, making a rough total of 8,000,000 to 9,000,000 lamps manufactured for con-

sumption. As the average life of a lamp is about 800 hours, and the average use is about two hours daily, we will see that lamp production and lamp consumption pretty fairly balance. But the total result is, to say the least, disappointing. It is a reasonable assumption, supported by various figures, that there are two gas burners per head of population in our cities; I believe gas consumption is often broadly estimated at about one active burner per head. Hence, it would follow that New York and Philadelphia to-day, if gas were abandoned or used as power at the point of production and electricity were universally adopted in its stead, would at once need all the dynamos and lamps now made and used for supplying the whole of the United States. And yet the combined population of the two cities barely reaches 3,000,000, or less than one-twentieth of the population of the country. The same basis of calculation would thus give us, for the United States, a dynamo lighting capacity of 100,000,000 incandescent lights and a lamp production of 600,000 lamps a day. If we cut that in two, so as to consider merely city population, there still remains an enormous field that has yet to be occupied.

Now, I do not think I overstate the case when I say that everybody in American cities would like to use the incandescent light, if possible. What then, have been the reasons that have so far stood in the way of gratifying their desires? Three reasons, I should answer. First, the high price of current; next, the scarcity of the supply; and third, the cost of the lamps. The first two reasons merge into each other. You have, in Philadelphia, one of the largest and best managed incandescent lighting stations in the world, and I shall show you a later one, a rival lately equipped and started in Boston. But both of these stations are in reality still producing on a retail scale, in view of the area to be supplied. I have shown that Philadelphia would need about 2,000,000 incandescent lights wired up. I doubt if the station I speak of can supply more than 100,000. Hence it follows that with gas to be consumed by 2,000,000 burners, and electricity by something short of 200,000, the odds as to price of light are very much against electricity. The mar-

vel is, that already, with one industry more than half a century old and the other barely ten years old, a parity of price has been established. A curious feature of the situation is that the coming of electricity has largely increased gas consumption in many instances. The old unit of ten candle-power gas no longer prevails, but gas men and electricians all talk now of sixteen candle-power units. Moreover, I have often noted, of late years, that in stores where gas has been adhered to, a great many more burners have been added, in order to gratify the eyes that have been attuned to a better means of illumination.

Can I promise the coming of a time when we who live in the cities can all have the electric light cheaply—in other words, at will and at no greater cost than gas anywhere within the limits of a modern city? Yes. With our present conditions, the time will come slowly, but I sometimes think the discontent which we feel in view of the slowness of its approach will hasten the perfection of new ideas and new apparatus. Many of you have heard my friend, Mr. Nikola Tesla, tell how by means of currents of high potential and high frequency, he could distribute current over very small wires and with it use lamps that have no filaments at all in them; so that he has at once cheap distribution and a lamp that never wears out. I know that when Mr. Tesla "arrives," as our French cousins say, gas will not be "in it," as our Bowery cousins say; but, meantime, we are confronted, not with a mere vision, but with the fact that gas is sold at $1.25 and $1.50 per thousand. Well, we shall steadily proceed to equalize things by increasing the quantity of current we manufacture. According to the Courts of Pennsylvania, we do manufacture current. We are pulling down our old stations and building greater; we are simplifying the machinery and installing larger units for the generation of current. We are also steadily reducing the price of lamps. We are trying many new types. Besides that, we are now witnessing the production of ingenious devices with the laudable aim of cutting down at will the consumption of current in any lamp, so that the incandescent light can be burned at different degrees of brilliancy. These are useful,

operative mechanisms, and promise to accomplish much in popularizing and cheapening the illuminant which is still new.

Beyond all that, we have a great variety of apparatus that is increasing the demand for current, and thus cheapening the supply. I refer chiefly to electric motors and to electric heaters. The introduction of these appliances means much to a central station, and therefore much to the public. The chief hours of lighting are usually limited between 5 p.m. and 12 midnight, with a maximum of only half that time. Gas works have been able to depend on the daytime use of gas for gas engines and for cooking and warming; but until lately central stations have had no corresponding day load, and they have been at a corresponding disadvantage as to opportunities of income and profit. But now the use of electric motors and electric heaters is changing all that. It is no uncommon thing for a central station to-day to supply current for hundreds of motors employed in an endless variety of work. These motors are jacks-of-all-trades and popular in each of those trades. They are cheap, easy to run, and economical of space. They generate no heat or smell, and they are obtainable in any size from fractions of a horse-power up to motors driving whole factories. The rates for current range from four to ten cents per horse-power hour. To-day, instead of having boilers and steam engines scattered all over a city in small, expensive units, the generating plant is located in a region where smoke and steam cease to annoy the neighborhood, and an electric motor becomes the medium of distribution. Going along our streets on torrid summer days and getting a whiff of hot air from the nether regions where a steam plant is in operation under the sidewalk, or in some dim, stuffy basement, I wonder to myself that this electric innovation does not make quicker headway. But the change is going on, and such cities as Philadelphia, New York and Boston now have literally thousands of horse-power in electric motors. Moreover, steam or gas is not the only agency utilized to drive the generators of current. Very soon Buffalo will have 100,000 horse-power on tap from Niagara, twenty miles

further down stream; and thus we shall see the contradiction on a grand scale of the old adage that you cannot grind with water that has run by.

The electrician is not so far advanced with heaters as with motors, but he has already reached firm ground. The heater to-day is at the same point of perfection as the motor had touched ten years ago. As a device it is fully operative, but it is still very inefficient. Its use depends, therefore, upon its improvement, upon a cheap supply of current, and upon the new features of advantage and comfort it may present. In some cities it is already a fairly familiar object. In Ottawa, Canada, it is in use in barbers' saloons, drug stores, livery stables and bakers' ovens, and is now being applied to the warming of houses and offices, current for all the devices being obtained by the utilization of the Chaudière Falls, whose name has thus contained a happy prophecy of their modern service.

Aside from the cost, it is obvious that there will be no carting in of coal, no disposal of ashes, no smoke, no soot, no dust to settle on furniture and tapestries, no sacrifice of the whole cellar to the heating system, no martyrdom in the kitchen during the summer, no fiery blasts from the register, no wintry breezes in the upper rooms, no bombardments of Alexandria in the steam pipes. On the contrary, there is the immediate noiseless heating of any room or of the whole house at any minute, the paradoxical keeping cool on a sultry March day, and warm on a bleak July day; the possibility of making coffee or grog in five minutes; the ability of keeping a foot-warmer warm all day and a bed-warmer warm all night; the chance of using one's cellar as a billiard room instead of a depot for Reading coal, against the next rise in price.

Back of all this is the great fact that wherever soft coal is used, electric heaters will help wipe out the smoke nuisance, with its grim attendant, fog. Fog and soot and smoke mean disease, and as we have, each one of us, to repel about a dozen infectious diseases every week of our lives, it is well to clear the atmosphere of everything that may give wings to the germs. The application of a smoke consumer to a

large central station is easy, while, as Chicago shows, it is still practically impossible to consume the smoke from thousands of individual coal fires. What a smoke fog means in London we may infer from the mortality statistics of 1879–80 when the deaths from bronchitis increased 331 per cent. above the average, and those from whooping cough 231 per cent.; or from the statistics of 1890 to 1892, when the blight of the London fog extended to the vegetation at Maidstone, the center of the hop region, thirty miles distant. Need we wonder that a recent brochure depicting the doom of London, describes the asphyxiation by fog of all her 4,000,000 inhabitants, save one man, who escaped as by a miracle, to tell the sad story.

Before I leave this branch of my subject, I would like to point out that electric heat, light and power will do even more to give us a cleanly, beautiful city if we burn up the refuse and rubbish in what are known as "destructors" instead of dumping them where they do the least good. In New York, we cart the loose refuse through long stretches of breezy city street, then bank it up carelessly on open barges and tow it out to sea—when not too rough. The Atlantic rejects it, as would any self-respecting ocean, and so it floats about until the vile jetsam spoils the whole range of bathing beach from Far Rockaway to Normandie-by-the-Sea. It may be the evidence of a high civilization thus to greet the enthusiastic newcomers from Europe with the contents of our dust bin, but I think the effect would be as fine if we burned the rubbish in a destructor on Liberty Island. It would then speak in parables through the welcoming torch of white electric flame that tells of a land where old things become new and where that which was outcast is transmuted into living elements of beauty and power.

I have now dealt with electricity in the modern city as applied to the communication of intelligence, the safety of buildings and streets, and the means of light, power and warmth. I come now to the vital and important questions of travel and transportation.

Five years ago the electric street railway was practically an unknown thing in America. The first statistics of the

industry were compiled by myself in 1887, and showed a baker's dozen of short, experimental roads, with crude apparatus, and handicapped by a grave suspicion on the part of the public that an electric motor was about as likely a means of rapid transportation as a balloon. Four years ago I sat in a national street railway convention at our national seat of government, and heard an indignant delegate complain that he was there for the purpose of learning how to shoe horses and dispose of manure—certainly not to listen to all this newfangled stuff about electricity.

Yet, as my presence here to-night and my subject would indicate, the electric railway, in a very special sense of the slang phrase, "got there." The suddenness and brilliancy of its development have been equalled only by the abuse and the calumny that have marked its advance. Like every new thing, it has had its shortcomings; like every great invention, it has still to pass through many stages of improvement; like many an innovation, it offends some tender sensibility or deeply-rooted prejudice; and the old battle that has been fought so often has to be fought again. Considering how universal among progressive peoples is the desire for good roads and swift travel, one is rather at a loss to understand why the electric railway is opposed; but I have not the slightest doubt that when an etheric railway is advocated in the year 1993, some slow ultra-conservative will rise in his wrath and say that electricity is good enough for him, as it was for his father before him. There is a curious revelation of prejudice in the remark of our own General Webb, in 1835, who, after a railroad journey with ladies from Boston to Providence, exclaimed in disgust: "To restore herself to her caste, let a lady move in select company at five miles an hour, and take her meals in comfort at a decent inn." I fancy I see the ladies of Philadelphia, *en route*, for New York, restoring themselves to their caste on this basis. And yet this utterance, or the horror-stricken protest of Philadelphia against the introduction of gas, I could match with many a passage from the American newspapers of to-day about the electric railway, with its "deadly trolley" and its "death-dealing wire."

[*To be concluded.*]

ENGINEERING PRACTICE AND EDUCATION.

By Gaetano Lanza, S. B., C. & M. E.,
Professor of Theoretical and Applied Mechanics, Massachusetts Institute of Technology.

[*Continued from p. 139.*]

Let us now consider briefly some of the functions of the electrical engineer, and the character of the work commonly known as electrical engineering.

The present extensive applications of electricity are of comparatively recent growth, and it is only of late years that such applications as are intimately connected with the work of the engineer have been developed to any great extent.

The realization of this class of applications is due especially to the great development of the methods for the electric transmission of power, and to the extension of electric lighting; although various other applications, such as electric welding, the telephone, the telegraph, railway signaling, etc., are also closely connected with engineering work.

Heretofore the civil engineer, or the mechanical engineer, so called, has not considered electricity as an essential part of his work, but as something which he need only cultivate if the special work in which he was engaged led him in that direction. But the signs of the times seem to be that before long the engineer will be so likely to meet with the use of electricity in one form or another, whatever be the special line to which he devotes himself, that it will become an absolute necessity for him to have a certain amount of training in that subjcect, as well as in such general subjects as mechanism, strength of materials, steam and hydraulics.

However, the term electrical engineer to-day is used to denote a mechanical engineer, having special training in the theory of electricity and its applications, and whose

special work is in the line of the practical applications of electricity. The greater part of his work is the usual work of the engineer, the remainder having to do directly with electrical appliances. It must be borne in mind that electricity, when used on a large scale, must be generated by some external source of power, as by a water wheel, or more commonly by a steam engine; that dynamos and electric motors cannot be operated without a power plant; also that the object of electric motors is to drive machinery of some sort.

Suppose, for instance, that the electrical engineer is called on to establish an electric light station. The engineering problems arising are, in a certain sense, similar to those which would arise in building and equipping a large factory, his special machines in this case being the dynamos and connected machinery and apparatus, the manufactured product being the light. He must determine the number, size, kind, etc., of his dynamos, switchboards, etc., having regard to the requirements of the service, to the amount of light he is liable to be called upon to supply, to the district in which the lights are situated, and making allowances for a reasonable growth. All this deals directly with the electrical side of the work. He must then proceed to locate the machines, having due regard to the work to be performed, and also to the arrangements of shafting, belting, pulleys, etc., by which they are to be connected with the source of power. These last are purely engineering questions.

Then he must locate and arrange his power plant; boilers, engines, etc., determining what kinds, what sizes, and how many he will use.

Then comes the arrangement of the whole system of power transmission from the engine or engines to the dynamos. Then comes the erection of buildings to contain the machinery, in which due consideration must be given to the questions of strength, of stability, of lighting, of heating and of ventilation; also to securing proper foundations for the buildings, and for engines and boilers, and other heavy machinery that cannot be placed on the floor of the build-

ing; also to the design and erection of a suitable chimney. Then of course questions of water supply and of drainage arise.

All these are engineering questions, and he will meet a number of others when he proceeds to carry the wires through the streets to the points where the light is to be furnished. If they are to be strung overhead on poles, the strength of the cables, the strength of the posts, etc., are important things to be considered. If they are to go underground, other engineering questions arise, such as the proper protection of the cables from moisture, etc., the means of running out branches from the mains, and other related problems.

Now, in the power station of an electric railroad, we have just such problems as the above, besides questions that arise in connection with the permanent way and the rolling stock; also, if the company intends to make its own machinery, in whole or in part, suitable shops must be built and equipped, such as boiler shops, etc.

I shall not attempt to give a description of such a power station, but will pass on to give as an illustration a summary statement of the different kinds of machinery manufactured by the General Electric Company.

Practically, these works might be said to manufacture machinery for electric power transmission and for electric lighting, but on close examination we find that these two divisions include a very large variety of machinery and apparatus. Thus, the first involves the making of dynamos, railway motors, tramway motors, mining locomotives, electric locomotives, snow-sweepers, trolleys, motors for stamp mills, mine hoists, elevators, air compressors, rock drills, mine pumps, blowers, cranes, rock-breakers, coal-cutters, coal-drills, etc., and, in addition, all the accessory electrical apparatus, including switchboards, voltmeters, ammeters, rheostats, resistance coils, etc.

Furthermore, the various systems of electric lighting—arc, direct incandescent and alternating incandescent lighting, involve the making of dynamos of the kinds suitable for each, switchboards, regulators, lamps, lamp fixtures and

a great variety of apparatus necessary in connection therewith.

Now, from what has been said, it is plain, I think, that much engineering work must be carried on in connection with the use of this machinery, but I will pass to a consideration of the factory itself, where these things are made, and, without attempting to give any adequate description of it, I will call attention to a few of its engineering features.

It comprises a large workshop for manufacturing machinery varying in size from a huge and heavy dynamo and motor, to the minute pieces that form the parts of a voltmeter or of an ammeter. Hence we have practically the same engineering features and problems that would be found in every large machine shop fitted with such a variety of tools as to be able to perform both heavy work and very light work, with the difference that in this case we find, in addition, special arrangements for doing the work that is peculiarly electrical, as the testing of the different parts of the machines, and of the entire machines by means of delicate electrical measuring instruments.

Now I have often enough detailed in one connection or another the engineering features that enter into the design and erection of any such plant, and I shall only say that there is opportunity here, which is taken advantage of, to use electric means of power transmission, and hence to not only introduce electric cranes, but also to drive a number of the individual machines by electric motors. This is a feature which is not peculiar to these works, for electric cranes are in general use in foundries, machine shops, etc., and the electric motor for the transmission of power, is coming into general use.

These works are building some large electric locomotives, making not merely the motors, but every part of the machines; while, by way of contrast, their lamp factory affords an instructive example of a well-organized shop for turning out small and delicate work. Finally, an important part of this great establishment is the very large draughting department, with a carefully arranged system by which drawings and blue-prints are kept so as to be readily accessible for reference.

Without dwelling longer on this and similar illustrations, I will say a few words about the telephone, a subject which most of my hearers will doubtless think is very remote from engineering; nevertheless we will find in connection with it a large amount of engineering work.

The wires have to be carried from the central exchange station to the points where the subscribers are situated; and they must be placed either overhead, underground, or sometimes under water. When they run overhead there are to be considered the strength of the poles, the manner of setting them firmly in the ground to enable them to resist any load they are liable to have brought upon them, and of strengthening them when necessary by guy ropes; the strength of the cable and the tension upon it, and the strength of the cross-pieces which carry the cables.

Now, when the installation is to be underground, the cables radiating from the exchange must be suitably arranged, so that any one of them can be taken out independently of any others. This arrangement involves very careful engineering. Then comes the consideration of how the cables shall be protected underground, how they should be arranged so that each one may be drawn out at any manhole in the street just as at the exchange, how to avoid gas pipes, water pipes, etc.

If the cable goes under water it must be covered like a submarine cable, and then sunk to the bottom as is done with telegraph cables. This becomes a little difficult sometimes when the tide and current interfere with laying it in the desired position.

The exchange building should be designed specially for its intended purpose, and should be made strong enough to stand the heaviest loads to which it can ever be subjected. One of the most complicated problems to solve is how to introduce cables from the street and carry them to some central point in the building without interference.

These illustrations will suffice to show that one who is not an engineer cannot be an electrical engineer, and that the greater portion of the work of the electrical engineer is such as to require a knowledge of other branches of engineering.

As our next illustration we will take refrigerating machines, their manufacture and operation in making artificial ice, but more especially in cooling rooms, the latter finding its chief application in cold storage; an industry of very recent growth, but one which is of the greatest importance both on sea and on land, and which is rapidly growing.

For a number of years ice has been made in warm countries by means of absorption machines. In these, a concentrated solution of ammonia contained in a vessel, called the generator, is heated, and the ammonia, thus distilled off, passes through a condenser, where its heat is abstracted from it, but where it remains under a considerable pressure. It is then allowed to expand into a coil arranged in a tank of brine, which is cooled by it to a temperature below the freezing point of water. The ammonia absorbs the heat of the brine, and is then itself absorbed by a weak solution of ammonia contained in a vessel called an absorber, with which the coil communicates. The solution of ammonia in the absorber, when it has become more concentrated, is pumped into the generator, and the process goes on continuously. Then the cans of water are placed in the chilled brine, by contact with which their contents are frozen; or, if the object is refrigeration and not ice-making, the chilled brine is pumped through a coil which passes through the room to be cooled.

Such a method as this is inefficient, and is not suitable for work on a large scale. Hence, until a better one was discovered and its success fully demonstrated in practice, no great development was possible for refrigerating machines.

The modern refrigerating machine is a compression machine, which is arranged as follows: A steam engine drives a compressor, which receives the ammonia in the form of vapor from the other end of the system and compresses it, heating it, of course, at the same time. The compressed ammonia passes into the condenser, consisting of a coil of pipe, on the outside of which water trickles, carrying off the heat from the ammonia and liquefying it. From here the liquid ammonia passes into a separator where the ammonia settles to the bottom, and the oil taken up in its passage

through the system rises to the surface, and is drawn off whenever it is deemed desirable. From here the liquid ammonia passes through a valve and expands into a coil of pipe, which passes through the brine in the brine tank, and here the brine is cooled, its heat being expended in the re-evaporation of the ammonia, which is then led back to the compressor while the brine is pumped through the coils in the rooms to be cooled, or placed in contact with the cans containing the water to be frozen.

Such machines require for their development and successful construction, a careful application of the laws of thermodynamics. For ice-making, they have become absolutely necessary in warm climates, and are used to a considerable extent also in cold ones. For cold storage they are needed everywhere. Cold storage necessarily demands a structure, in which, even in the hottest weather, a series of rooms are kept so cool that meat, eggs, vegetables, etc., stored therein will be preserved from decay. By the use of cold storage on shipboard, meat can be sent across the ocean, and the benefits conferred by it on land are so evident as hardly to need enumeration. Fruits, for example, gathered at the proper season, may thus be kept in good condition for a long time, and brought to market when such products are entirely out of season; and meats, eggs, etc., may be kept fresh for a long time.

The building of the Quincy Market cold-storage plant in Boston is on piles. The outer walls are double, having between them an air-space, which is packed with shavings. The inner walls are packed in the same way. The building is located near the harbor, so that cold water from the dock can be pumped up for use in the condensers. The building had to be adapted to: (1) the storage; (2) the plant; (3) the conveyance of the brine. In arranging the building for the storage, it was necessary to provide a suitable number of rooms to accommodate the different classes of food products, and these rooms required to be insulated from their surroundings, so that the temperature of each one could be kept at the desired point, independently of the others.

There are two engines, each running a compressor. The

water for cooling the ammonia in the condenser is pumped up from the dock, and, after performing this duty, is returned to the dock by gravity.

The brine tank contains 4,500 gallons, and has a capacity of 250 tons, only 100 of which are at present utilized; but the intention is to put in a new compound engine of larger capacity (about 150 horse-power, I think) as soon as business warrants it. The usual method of refrigeration is by means of a coil of brine pipe placed around the inside of the room. At the Quincy Market, however, an indirect system is used for some of the rooms, the air being drawn by a fan over a coil of cooling pipes erected at one place in the room.

Electric lighting is used throughout the building. A machine shop and piper's shop are being added. The tank room is, of course, well protected from heat by thoroughly packing the walls, roof and floors.

If you should walk through the building and look into the different rooms, you would find them filled with all sorts of perishable materials in a good state of preservation. You would find pears, peaches and all sorts of fruit and vegetables stored here to be kept for a later market. Elsewhere you would find poultry and other meats in a frozen condition. You would observe also that the temperature of each room is regulated to a nicety, according to the requirements of the products stored, or intended to be stored, in it.

Doubtless, the largest establishment in this country for the manufacture of refrigerating machinery is that of the De la Vergne Company, of New York. The special features of the refrigerating machine which this firm manufactures are that oil is introduced with the ammonia into the compressor cylinder, partly for lubrication, partly for the sake of preventing leakage, partly for decreasing the clearance space, and partly to absorb a portion of the heat developed during the compression. Besides these there are also certain special features of construction, some of which are intended to decrease the number of joints that have to be made up, and thus to decrease the leakage.

The works are very extensive, including three large main

buildings, and a fourth building, which contains a blacksmith shop and a pipe shop.

These works are quite modern and have, of course, the general features of a modern plant for the manufacture of machinery. An erecting shop has lately been added, and here every attention has been paid to securing light and to convenience of handling materials, and every separate machine is run by its own special electric motor. This avoids the use of shafting, with its pulleys and belts.

Turning our attention next to those industries in which chemistry plays the leading part, we enter the field of the chemical engineer. We will take up only two of his specialties, viz.: the refining of sugar, and the manufacture of paper.

Sugar Refining.—I will begin by outlining briefly the process that must be followed, without attempting much detail; and in doing so, I will have in mind the routine of operations practiced in the Standard Sugar Refinery, at South Boston.

The raw sugar is received at the refinery in bags or sacks, from which it is emptied into the melting kettles. These are large, covered, cylindrical chambers built of brick and cement, and provided with a number of coils of perforated steam-pipes. Steam is now let on. This melts, and of course, dilutes the sugar. The resulting liquid, containing about fifty per cent. of sugar, is now pumped to the blow-ups, which are large tanks, situated higher up in the building. Into these tanks, air is blown for the purpose of keeping the liquid in a state of agitation and consequently thoroughly mixed. This counteracts the tendency of the liquid to local solidification, and at the same time reduces its temperature. A little lime is here introduced to neutralize the acidity, if there be any.

From the blow-ups, the liquid flows by gravity to the filter-pans. These are flat, shallow pans with series of holes in the bottom, and below each hole is a nipple to which is attached a bag filter. This consists of a large bag of coarse material, confined within a smaller bag to keep the large one from being distended, and failing to perform its functions. The

liquid is now filtered through these bags, and the syrup passing through them is then ready to be taken to the charcoal filters.

When the bags have become so choked up with dirt as not to filter well, they are detached from the filter-pans, and the adhering material is emptied out, and taken to a filter-press. The syrup here squeezed out is taken to the melting kettles, while the residue, which is only dirt, is thrown away. The bags are then washed by passing them through running water and wrung out between rollers. The water in which the bags are washed is then sent back to the melting-kettle.

The bags are now in condition to be used again by placing the large bag inside of the small one as before. This was done with more or less difficulty by hand, until a simple machine was devised, in which automatic fingers, attached to a piston moving in an upright tube, drew the bag into the tube with the aid of a partial vacuum. The large bag is then dropped into the sheath or outer bag, the rapidity of the drop being regulated by the amount of air admitted behind the piston.

The syrup that has passed through the bags is transferred by a pump to the bone-charcoal filters. These are 20 feet deep and 12 feet in diameter. The syrup is thus decolorized, and it then goes to the vacuum pans, where the water is boiled off, and the sugar is formed. The sugar is then dropped into a conveyor, where it is made to travel along by a screw and delivered to the centrifugal machines. The water is here driven out, and the sugar is left white, and very nearly dry.

Next it is granulated. For this purpose it is introduced into the upper end of a long cylinder inclined a little to the horizontal, and the rotation of this cylinder alternately raises it and lets it fall, at the same time feeding it slowly forward to the lower end, while a series of hammers constantly jar the cylinder so that the sugar shall not stick to the sides. In this way the sugar is dried. On leaving this cylinder it is carried on a belt-carrier to the bin where it is stored. As with grain in a grain elevator, no attempt is

made to keep separate the sugars made from the different lots of raw sugar.

Such, in brief, is the process through which the sugar is carried, but the bone-black must undergo a process also. When the syrup has filtered through the bone-black for a certain length of time, the latter is found to be dirty, and has to be cleaned. For this purpose the filters are opened near the bottom, and the bone-black is drawn out with a rake, and conducted into vertical retorts where it is heated to redness, and the dirt is thus burned off. The bone-black is then allowed to cool to a certain extent before the retorts are opened, and after it has cooled down further it is returned to the filters. The final cooling is accomplished by running the bone-black into a kettle provided with pipes through which cold water circulates. Under the retort is a fire which heats the bone-black to a temperature of about 700°, and it is left at this temperature for several hours. Now, as it cannot be exposed to the air at once, it is passed into sheet iron flues, and allowed to stay there until it cools to a temperature of 400°. From here it is transferred to a hopper, and this transference must be done at a regular rate and in measured quantities. This is accomplished by some very ingenious special machinery. From the hopper the bone-black is dropped upon a belt-carrier, which takes it to the kettle already referred to. From this it is taken by another belt-carrier, provided with little buckets, and carried to the room where the tops of the filters are situated, and, finally, a horizontal belt-carrier delivers it to the filters.

The above is a very brief description of the various processes that have to be carried out, and a successful performance of the work demands the greatest care and nicety of operation at all points, especially in properly sorting the different qualities of the syrups that come from the bone-filters, and in operating the vacuum pans.

Of course, the superintendent must look carefully after these matters, and chemical analyses have to be constantly made, since the least carelessness in carrying out the process may result in very serious loss to the company. Never-

theless, the process and the greater part of the chemical work become in time largely a matter of routine.

When, however, we undertake to carry out any such complicated series of processes we have to use a large amount of machinery, and extensive buildings of sufficient strength and stability have to be built.

It is frequently necessary to build wharves or quays to receive the vessels that bring the raw sugar; and to erect buildings which must provide space and facilities for storing the raw and refined sugar, and hence must sustain heavy loads. Then the portions of the building where the various parts of the process are to be carried on must be so designed as to be most conducive to economical handling. Then there is considerable opportuniy for devising special machinery and special arrangements to accomplish special objects. Thus, the syrups are usually transported from one place to another by pumping, and part of this pumping is done before it has been passed through the bag filters. All this means that we must have pumps that can raise a thick liquid, and which will not become clogged with dirt that comes from the melting kettle. Then, for transporting the sugar from place to place, and also for transporting the bone-black, belt-carriers are used, *i. e.*, endless rubber belts. In the refinery which is now being built at Greenpoint, L. I., which is the largest single refinery belonging to the Trust, and in which the greatest care is being taken to introduce the most modern and approved methods and machinery, the coal is received at a long distance from the boilers and is carried to them on belt-carriers.

Another labor-saving device is the mechanism already referred to, for sheathing the filter bags. Another is the machinery for delivering the bone-charcoal at a known uniform rate, from the sheet-iron flues to the hopper. Then there is machinery for packing, and for lifting barrels, etc. The special sugar machinery likewise (such as centrifugal machines, vacuum pans, etc.,) must be very carefully made and requires nice engineering skill in its design and construction. Besides this, a large amount of very nice engineering work must be done in connection with the evaporation in the

vacuum pans, which are sometimes run with triple effect, the three evaporations being carried on successively, the steam for one being furnished by the evaporation in the next preceding one. Then of course there are the boilers, the engine or engines, the chimneys, etc. Evidently, therefore, a very great amount of engineering work must be done in order to make the plant a success.

As another illustration let us take the manufacture of paper from wood pulp, for which purpose I will give a brief description of the processes carried on at the works of the Russell Paper Company at Lawrence, Mass. The kinds of wood used are poplar and spruce. The wood is cut into chips, and these are mixed with a liquor which attacks all the ingredients of the wood except the cellulose. This liquor is put, with the chips, into a boiler or digester, into into which steam is introduced and in which the mixture is cooked for a suitable length of time. The mixture is then drawn off and washed, and the water and impurities are thrown away, and pure cellulose is left. This, mixed with water, constitutes the pulp. To make a satisfactory product, two different kinds of pulp, sulphite pulp and soda pulp are used, which are mixed in proper proportions, viz.: the sulphite pulp alone would make too harsh a paper, while soda pulp alone would make too weak a paper. The first is used to give strength to the product, and the second softness and delicacy. The sulphite pulp is made by treating the chips with an aqueous solution of sulphite of lime, the chips, liquor and steam being mixed in a spherical boiler which is kept rotating during the cooking. The soda pulp, on the other hand, is made by boiling the chips in a solution of hydrate of soda, and, instead of using a rotating boiler, the chips and the liquor are placed in a vertical cylindrical vessel called a digester. This vessel is provided with a perforated plate near the bottom, and on this plate are placed the chips. The steam is then introduced below the plate, and the liquor is caused to circulate through the chips, during the cooking operation.

In both cases, after the cooking operations are completed the pulp is pumped up to a beating machine, where it is

thoroughly mixed, and the fibres are drawn out by causing them to pass between revolving beaters. Here it is also more thoroughly washed than it was after leaving the boilers or digesters.

In the case of the soda pulp it is sometimes bleached in the troughs in which the washing and heating is done.

After the pulp leaves these troughs it is made to pass through a series of very fine screens of metal plates having a series of thin slats. Thence it goes to the wet machine, which is a trough through which a continuous flannel roll is made to pass. The pulp adheres to the flannel and the water drops off. Then the flannel, with its layer of pulp, is squeezed between several sets of rollers from which the pulp layer emerges as a kind of thick paper, but destitute of consistency. Then, if it has not been previously bleached, it is conveyed on trucks to the bleaching pots. In these it is placed, together with the bleaching liquid, and the whole is stirred by agitators. From here, when the bleaching is finished, the pulp is conducted to a room with a perforated floor, where it is washed by a stream of water from a hose, leaving the bleached pulp on top of the false floor.

Next follows the mixing operation. In the trough of the mixing machine are placed the sulphite and soda pulp in the desired proportions, together with any other ingredients that may be desired, such as clay to make the paper take ink, sizing, resin soap, etc. By suitable machinery the materials are caused to travel round and round in this tank until they are thoroughly mixed. For the finer papers a Jordan engine is used instead.

After this the pulp is ready for the paper machine proper, which may be a Fourdrinier or a cylinder machine. In either case, the pulp is caused to adhere to a layer of cotton or wool, which forms, as it were, an endless belt, the water dropping off, and the pulp being carried along on this cloth, gradually passes between pairs of rolls, the first pair usually making the water mark. The pulp then reaches the calender rolls, inside of which steam circulates. Here the pulp is dried, and, as it were, ironed, and receives a gloss. It is

then rolled and subsequently cut into sheets of any desired size.

The foregoing is a very brief description of the principal steps only. The following important details have still to be mentioned:

(1) When the wood is received at the mill, the bark and any other roughness are removed by a special machine, made somewhat on the principle of a milling machine. Any large knots are then drilled out, a machine being also provided for this purpose. The log is then placed in a machine containing a set of revolving knives which chips off the wood obliquely to the grain. From this machine the chips are carried by belt-carriers to the upper part of the building, where they are led to hoppers over the boilers or digesters respectively.

(2) The sulphite of lime solution is made as follows. On an upper floor are three closed tanks, arranged on three different levels and so connected that a liquid in the upper one, when it reaches a given level, will overflow into the second one, and in like manner from the second into the third. When it reaches a given level in the lowest tank it overflows into an open tank placed at a still lower level, and directly over the boilers. Above the system of three closed tanks is another open tank containing lime water, which flows continuously from this tank downwards through the entire system. In the basement is a furnace for burning sulphur, and thus forming sulphur dioxide, and the passage through which this gas escapes from the furnace leads into the lowest of the system of three tanks, then into the next and then into the upper one, from which it is pumped out by a vacuum pump, which draws the sulphur dioxide and the accompanying nitrogen through the solution in the three closed tanks. The sulphite of lime thus formed overflows into the lower open tank, from which it is delivered by means of a hose to the boilers.

(3) The hydrate of soda is made by boiling soda ash and lime water by means of a current of steam passing through a coil of perforated pipes within the boiler. The hydrate of soda is drawn off, and the carbonate of lime is thrown away.

(4) The material washed out from the pulp in the soda process is, of course, very dilute, but it is nevertheless, desirable to reclaim and to re-employ the soda. For this purpose the liquid is reduced in a Yaryan evaporator to the consistency of molasses, after which it is placed in a revolving drum, open at both ends, one end communicating with a furnace, and the other with the chimney. The inside of this revolving drum is conical. The material is thus burned, and comes out as a black ash, consisting of soda ash, carbon ash and a little sand. This black ash is leached with water, which dissolves out the soda ash, leaving behind the other ingredients, and we thus have again a solution of soda ash from which to make the liquor.

Here again we have buildings, tanks, furnaces and other constructions to erect, and a very large amount of machinery to operate and keep in repair, even if we do not have to design and build it.

I have cited, in these three lectures, a number of examples of industries where the work of the engineer is required, and, although these are only a few examples selected from an almost countless number, they will, nevertheless, show us much better than can any definition that can be framed what is the range and what the character of the work of the engineer.

Whenever a structure is to be erected, be it a bridge, a breakwater, a furnace, a tank, or a building, or be it what it may, in order that it should answer its intended purpose it must be erected in accordance with correct engineering principles; and the same is of course true of machinery. Regard must be had to its strength, to its stiffness, and to the efficiency and economy with which it can perform its functions.

Having discussed the nature and the range of the work of the engineer, we are now prepared to consider what kind of an education should be given to a young man who is to make engineering his life work, and this I shall proceed to discuss in the next lecture.

[*To be concluded.*]

THIN FILMS OF GOLD.

One of the interesting exhibits made at the recent *conversazione* of the Royal Society, held June 13, 1894, was that of Mr. J. W. Swan, F.R.S., who presented a number of specimens of leaves of gold of extreme thinness, which had been prepared by the process of electro-deposition. From a brief notice of the exhibit, published in London *Nature*, it appears that it represented an attempt by Mr. Swan, to produce gold leaf by electro-chemical, instead of mechanical means. "The leaves were prepared by depositing a thin film of gold on a highly polished and extremely thin electro-copper deposit. The copper was then dissolved by perchloride of iron, leaving the gold in a very attenuated condition. The leaves were approximately four-millionths of an inch thick, and some of them mounted on glass showed the transparency of gold very perfectly when a lighted lamp was looked at through them."

It will doubtless prove somewhat of a surprise to Mr. Swan, to learn that identically the same method of procedure for the production of films of metal of extreme tenuity was described and illustrated by Mr. A. E. Outerbridge, Jr., in a lecture delivered before the Franklin Institute in 1877, an abstract of which was published in the *Journal*.* At the stated meeting of the Institute held May 16, 1877, the then resident Secretary, the late Mr. J. B. Knight, made reference in his monthly report to the thin gold films produced by Mr. Outerbridge in the following terms:†

Transparent Gold.—In the course of a lecture on gold, delivered before the Franklin Institute, on February 27th last, Mr. A. E. Outerbridge, Jr., of the Assay Department of the Mint in this city, gave an account of some experiments he had made, with the view of ascertaining how thin a film of gold was necessary to produce a fine gold color.

The plan adopted was as follows: From a sheet of copper rolled down to a thickness of $\frac{5}{1000}$ of an inch, he cut a strip $2\frac{1}{2} \times 4$ inches. This strip,

* *Vide Jour Frank. Inst.*, ciii, 284.
† *Vide Jour. Frank. Inst.*, ciii, 369.

containing 20 square inches of surface, after being carefully cleaned and burnished, was weighed on a delicate assay balance. Sufficient gold to produce a fine gold color was then deposited on it by means of the battery; the strip was then dried without rubbing, and re-weighed, and found to have gained $\frac{1}{10}$ of a grain, thus showing that one grain of gold can, by this method, be made to cover 200 square inches, as compared to 75 square inches by beating.

By calculation, based on the weight of a cubic inch of pure gold, the thickness of the deposited film was ascertained to be $\frac{1}{250400}$ of an inch, as against $\frac{1}{254850}$ for the beaten film.

An examination under the microscope showed the film to be continuous and not deposited in spots, the whole surface presenting the appearance of pure gold.

Not being satisfied, however, with this proof, and desiring to examine the film by transmitted light, Mr. Outerbridge has since tried several methods for separating the film from the copper, and the following one has proved entirely successful.

The gold plating was removed from one side of the copper strip, and by immersing small pieces in weak nitric acid for several days, the copper was entirely dissolved, leaving the films of gold, intact, floating on the surface of the liquid. These were collected on strips of glass, to which they adhered on drying, and the image of one of them is here projected on the screen, by means of the gas microscope.

You will observe that it is entirely continuous, of the characteristic bright green color, and very transparent, as is shown by placing this slide of diatoms behind the film. By changing the position of the instrument, and throwing the image of the film on the screen by means of reflected light, as is here done, you will see its true gold color.

Mr. Outerbridge has continued his experiments, and, by the same processes, has succeeded in producing continuous films, which he determined to be only the $\frac{1}{2758000}$ of an inch in thickness, or 10,584 times thinner than an ordinary sheet of printing-paper, or 60 times less than a single undulation of green light. The weight of gold covering 20 square inches is, in this case, $\frac{1}{1000}$ of a grain; one grain being sufficient to cover nearly 4 square feet of copper.

As you see, the film is perfectly transparent and continuous, even in thickness, and presents all the characteristics of the one shown before. That a portion of the image appears darker, is due to superposed films, the intensity of the green color being proportioned to the thickness through which the light passes. * * * *

It may be stated, in conclusion, that the mode of procedure above described was patented by its author* under the title "Manufacture of Metallic Leaf." In his patent the inventor describes, as "a new and improved method of

* U. S. Patent, 198,209, Dec. 18, 1877.

manufacturing gold leaf, silver leaf and other metallic leaf," the above-named method of electrical deposition. As suitable mediums to support his films, he mentions copper in thin sheets, and paper, shellac, wax, etc., made conductive upon the surface which is to receive the deposit.

For removing the deposited film from copper and paper, Mr. Outerbridge describes the use of a bath of dilute nitric acid, or of perchloride of iron. In the case of the shellac, wax, etc., alcohol, benzine and other solvents are referred to.

While they detract neither from the interest nor genuineness of Mr. Swan's work, these circumstances are recalled in justice to Mr. Outerbridge, to whom priority undoubtedly is due. W.

DRILLING FOR OIL AND NATURAL GAS IN THE VICINITY OF PHILADELPHIA.*

By Oscar C. S. Carter,
Professor of Geology and Mineralogy, Central High School, Philadelphia.

There have been several attempts made recently to drill for oil and natural gas near Philadelphia, notwithstanding warnings of failure from scientific experts. There seems to be a kind of fascination and an air of mystery in searching for gold, silver, oil or natural gas, which, apart from their value, lead men to spend much money and time in prospecting localities, which have never yielded anything in the past, and, from a geological standpoint, will never yield anything valuable in the future. True it is, beyond all doubt, that oil has been found in the older as well as the newer rocks, and nearly every geological horizon from the silurian up to and including the tertiary has yielded oil. It is not, however, evenly distributed through all formations. The silurian, devonian and tertiary rocks have yielded most of the oil of the world. It was formerly thought that the devonian rocks were the oldest that would yield oil, but when gas was discovered in the Findlay field and oil in the

* Read before the Chemical Section, June 19, 1894.

Lima belt in Ohio, in 1886, it brought the limit of the oil-bearing rocks down into the lower silurian formation. The oil of the Lima belt was found in the Trenton limestone, not very far distant in a geological sense from the archæan granite. This was a great surprise to many who did not expect oil would be found in such a low horizon near the bed rock of the continent. The Trenton limestone of Ohio is now regarded as one of the most important sources of oil and natural gas in the world. In Indiana, in July, 1886, the combined flow of all the wells from actual testing and estimates was found to be 500,000,000 cubic feet of gas per day. Many of the gas wells have averaged 1,000,000 cubic feet per day. The Karg well is the largest of the Findlay district, and it is estimated that 1,500,000,000 cubic feet of gas from this well escaped utilization and were entirely wasted. In many small towns, over 700,000 cubic feet per day were wasted in working up booms and furthering real estate schemes. Laws have been framed for every conceivable purpose, and the rights of man are zealously guarded, but nothing has been done to prevent the criminal waste of Nature's richest gifts, which, in a few years, will exist only in history. The oil of the Trenton field is equally abundant; many of the wells have yielded 1,000 barrels per day, and the product of the Lima belt for 1888 was 9,682,683 barrels of oil. The Lima oil is black and heavy and contains sulphur compounds which have a disagreeable odor and are removed with difficulty in the refining process. Particular mention has been made of this Trenton limestone, because we have the silurian limestone, of which the Trenton is a part, within a few miles of Philadelphia.

The Schuylkill or Chester Valley is an immense trough of jointed, fissured and steeply dipping limestone. If oil or gas ever existed there it escaped ages ago. The limestone of Ohio, on the contrary, is as level as a floor, the slope being but two or three feet to the mile. It must also be remembered that oil at Lima is found at a depth of 1,300 feet. It takes sixty days to drill a well, while the silurian limestone near Philadelphia is found on the surface outcropping along the Schuylkill at angles of from 45° to 60° for a distance of

four miles below Norristown. Ever since Trenton oil has been found the sound of the drill has been heard in every State from New England to the Rocky Mountains, searching for this new oil and gas rock of Ohio. It is easily reached in many States, but does not contain oil, because the conditions are not the same. The Trenton limestone is only productive in the part which is a dolomite or magnesian limestone; the non-magnesian limestone has not yielded oil. Besides being horizontal and porous, it must be favorably situated to the surrounding strata for the accumulation of oil.

One of the most interesting experimental wells for natural gas or oil was drilled at Fitzwatertown, twelve miles from Philadelphia. There were stories told in the past by the farmers of the vicinity of a slight scum of oil appearing on the water in the spring-houses, and that bubbles of gas would come up through the water of the creeks, so that some were not surprised when operations were begun. Fitzwatertown is a country village on the Limestone Pike; the nearest railroad station is Edge Hill, on the Bethlehem branch of the Reading Railroad. The drilling was commenced by a stock company, and hundreds of acres were leased. The sinking of the well began on an eight-acre farm owned by Elijah Lukens. *The Philadelphia Inquirer*, of February 16, 1890, says: "The drillers worked day and night from that time onward; many precautions to keep the work secret were inaugurated. The rig was boarded in, and a rudely painted sign, nailed on the outside, announced that without a permit from the president, admission could not be obtained. The story the gossips talked about was this: Three weeks ago the driller, James H. Moore, and foreman Sclocomb noticed a regular puff, puff, whenever the drill was lifted, experience in the Bradford County fields led them to believe that natural gas had been struck, though at a depth of but 400 feet they regarded this as improbable. A sort of cap or reservoir arrangement, constructed of tin and topped with a key and burner, was placed over the hole to allow an accumulation of gas. In half an hour the key was turned and a match applied to the burner; a steady

mellow flame resulted when the key was half turned on. At full head the pressure was so great that the flame was extinguished. The company, though jubilant at the success already attained made another test with a larger reservoir, and the result more than satisfied their expectations."

I visited this well May 24, 1890. Three men were at work with a regular oil well derrick and apparatus and a small engine of fifteen-horse power. In drilling, they reached water or quicksand at a depth of ten feet; then limestone was reached. The strata here are nearly vertical, and much trouble was experienced as pieces broke off and fell down the well. There was much difficulty in keeping the drill hole straight. It is much easier to drill horizontal strata.

The drill passed through 330 feet of silurian limestone before the so-called Potsdam sandstone was struck; the well was then probably about 460 feet deep. An examination of the drillings showed me that the drill was then passing through the so-called Potsdam sandstone, which has never yielded oil or gas in any locality; about 130 feet of Potsdam had been drilled. The well was cased with iron pipe to a depth of 330 feet or through the limestone. It is a wet well; the water rises to within ten feet of the surface. The sand pump was put down that afternoon, and the well cleaned and a new drill put on, but not the slightest odor or indication of gas could be observed at the mouth of the well. The most interesting feature about the place was a pond of clear and sparkling water about twelve feet distant from the derrick; the sand or quicksand in the bottom was in continual motion. One of the workmen procured a pole, and on pushing it down through the sand bubbles of gas came up by the hundred. There was a small gasometer of ten gallons capacity floating in the pond, it was furnished with a stop-cock. On turning this I noticed an odor of gas, and on lighting it found it burned with an almost invisible flame. You could scarcely, in fact, see it in daylight, but on approaching a splinter of wood to it the wood at once took fire.

It may have been marsh gas. No analysis was ever made. There seemed to be no decomposing vegetable matter in

the pond. The drillers were very sick of their work. After they had drilled 550 feet they left, but the contract stipulated that they were to drill 720 feet before stopping. If they stopped before that depth was reached, then the company was to have the use of his plant one day for each foot that remained to be drilled. The plant was finally sold at sheriff's sale, although the company was entitled to the use of it for 170 days. Nothing further was done, and the well was abandoned. Not long after the failure of the well at Fitzwatertown, a deep well was drilled for oil and gas in Bucks County, not far from Philadelphia, in the new red sandstone of triassic age. This well was over 1,000 feet deep, and passed through beds of sandstone, red shale and slates. A bed of black slate, containing coaly matter, was encountered. This is the same bed of slate that was met with in drilling all the artesian wells at Lansdale, Montgomery County, Pa., in the new red sandstone (see *Franklin Institute Journal*, September, 1893). The same bed of coaly slate was passed through in drilling the Duffield well several miles distant, on the Stony Creek Railroad (see *Proceedings American Philosophical Society*, Vol. XXIX, May 25, 1891). Another experimental well for oil and gas was drilled at Valley Forge, in the Potsdam sandstone, with the usual result.

Not long afterward, there was reported a find of crude petroleum near Doylestown, Bucks County. It was announced that what seemed to be a rich crude oil was oozing out of the ground on the small farm of William Eisenhart. While Mr. Eisenhart was working in his cornfield, he came upon a pool of water covered with a heavy scum of oily substance. He found that a stream of oily fluid was oozing out of the ground and covering considerable space, finally finding its way to Cook's Run, a small stream running near by. Several citizens from Doylestown visited the place of the supposed rich discovery, and were outspoken in their belief that oil exists in paying quantities at no great distance below the surface. Mr. Eisenhart sent me a sample of this water for analysis. Qualitative tests showed much iron and organic matter, and a black substance held in suspension, but not the slightest trace of oil was present.

State Geologist Lesley tersely discusses the question where oil and gas will not be found in Pennsylvania, in the following words: "First of all, there can be no gas stored up in the oldest rocks. This at once settles the question in the negative for the whole southeastern third of the State. To bore for gas in Bucks, Montgomery, Philadelphia, Chester, Delaware, Lancaster, York or Adams Counties would be simply absurd. Secondly, there can be no gas left underground where the old rocks have been turned upon edge and overturned, fractured and re-cemented, faulted and disturbed in a thousand ways. If there ever was any, it has long since found innumerable ways of escape into the atmosphere. This settles the question in the negative for all the counties of the great valley—Northampton, Lehigh, Berks, Lebanon, Dauphin, Cumberland and Franklin, as any one can see by looking at the present condition of their limestone, slate and sandstone formations. Thirdly, there is not the least chance that any gas is left underground in the greatly folded, faulted, crushed and hardened formations of the middle belt of the State—Carbon, Schuylkill, Lehigh, Luzerne, Columbia, Montour, Northumberland, Union, Snyder, Lycoming, Perry, Juniata, Mifflin, Centre, Clinton, Huntingdon, Blair, Bedford and Fulton Counties. Where the oil and gas rocks rise to the surface in these counties, as they do in a thousand places, they show that all their oil and gas has escaped long ago. Fourthly, where the rock formations lie pretty flat and have remained nearly undisturbed over extensive areas, as in Wayne and Susquehanna, parts of Pike and Lackawanna, Wyoming, Bradford, Tioga, Potter and all the counties west of the Allegheny Mountains—there is always a chance of finding gas (if not oil) at some depth beneath the surface, determined by the particular formation which appears at the surface; but, as yet, we have no satisfactory evidence of the existence of quantities of rock gas in any of these counties east of Potter. Fifthly, wherever the bituminous coal beds have been changed into anthracite or semi-bituminous coal, it is reasonable to suppose that the same agency which produced the change, whatever it was, must have acted upon the

whole column of formations, including any possible gas rock at any depth. Sixthly, wherever rock-oil has been found, there, and in the surrounding region, rock-gas is sure to exist. In the deep Erie well, the Trenton was reached. In the Canada well on the south shore of Lake Ontario, the Trenton was pierced. Several wells in New York State penetrated it. In no case has there been any profitable return of either oil or gas. And if this happens under the exceptionally good conditions in central and western New York, where the formation is very fossiliferous, lies nearly flat and can be easily reached, what chance is there of success for those who bore in the uplifted and dislocated and poorly fossiliferous strata of Pennsylvania? Where the Trenton is brought to the surface, it shows plainly that whatever petroleum or rock-gas was once distilled from its fossil corals and shells has, ages ago, escaped from it."

ON THE INTERACTION OF BORAX, CARBONATES AND POLYHYDRIC ALCOHOLS; ALSO ON THE COMPOSITION OF BORAX.*

By Lyman F. Kebler.

It was the profund observation of Lord Bacon that "In all generations and transformations of bodies, we should inquire what is added, what remains and what is lost; what is united and what is separated." This is the true character of inductive philosophy, careful observation and rigid analysis. These sentiments are applicable to these questions as well as to the many difficult problems constantly inviting our sober thoughts.

From statements made in certain† lines of literature we are led to infer that on mixing *borax*, *sodium bicarbonate* and glycerol, a certain chemical reaction ensues in which there

* Read at the meeting of the Chemical Section held June 19, 1894.

† National Dispensatory, 5th ed., p. 1455.

are formed normal sodium carbonate and carbon dioxide. This is equivalent to saying that there is no interaction, as far as the carbonate is concerned, when a normal alkaline carbonate is employed instead of the acid carbonate.

Recently, the writer had occasion to establish the presence or absence of sodium bicarbonate as an adulterant in a sample of borax. After having exhausted all the available tests of reputed value without obtaining definite results, recourse was sought in the above reaction but it was soon discovered that the same reaction resulted with the normal carbonate, except that it was less energetic. Being somewhat surprised at this unexpected phenomenon the writer made an investigation and soon found that the same result had been reported by C. Jehn* some six years previously.

D. Klein† and the same year A. Senier‡ and A. J. G. Lowe showed that an acid reaction resulted when borax is dissolved in glycerol. W. R. Dunstan§ also made a comprehensive report on the reaction of polyhydric alcohols and borax. The acid reaction results not only with the polyhydric alcohol glycerol, but also with many other polyhydric alcohols, as mannitol, erythrol, levulose, dextrose, glucose, α-galactose and β-galactose, Undoubtedly many other polyhydric alcohols, as sucrose, raffinose, lactose, dulcitol, quercite, etc., would produce the same reaction if subjected to the proper conditions.

It is reported that borax is decomposed even by water, for Rose‖ has shown that strong solutions of this salt give precipitates of silver borate, while dilute solutions act like an alkali, precipitating argentic oxide.

The acidity is unquestionably due to the transformation of the borax into sodium metaborate and boric anhydride, the latter uniting with water to form boric acid. As significant evidence substantiating the above statement, it may be noted that no acid reaction results in the absence of water,

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* 1888, Arch. der Phar., (III), **26**, 495; Am. J. Pharm., **60**, 455.
† 1878, Bull. Soc. Chim., **29**, 195; Comp. rend., **86**, 826.
‡ 1878, Pharm. J. Trans., (III), **8**, 819.
§ 1883, Pharm. J. Trans., (3), **13**, 256; Am. J. Pharm., **55**, 447.
‖ Mendeléeff's Principles of Chemistry, Eng. Ed. Vol. 2, p. 60.

for on using anhydrous borax, anhydrous glycerol and elevating the temperature so as to expel the water formed during the reaction, no acid reaction results.

Confirmatory evidence of the correctness of this view of the composition of borax may be found in the formation of tetraboric acid. When orthoboric acid is heated, there are formed at 100° C. metaboric acid and water ($H_3BO_3 = HBO_2 + H_2O$); at 160°C. it yields tetraboric acid and water ($4H_3BO_3 = H_2B_4O_7 + 5H_2O$); at a still higher temperature all the water is eliminated and boric anhydride is formed ($H_2B_4O_7 = 2B_2O_3 + H_2O$).

Tetraboric acid is the intermediate compound from which only a portion of the water has been eliminated; that is, it is neither metaboric acid nor boric anhydride, but a mixture of the two. In that borax is a salt of tetraboric acid, it must necessarily share an analagous composition. Direct evidence that borax is so constituted is wanting, but indirect evidence appears to be ample.

The avidity of boric acid is unity when nitric acid is taken as 100. Boric acid displaces carbonic acid, and *vice versa*, depending on the conditions; consequently, the avidity of carbonic acid must be nearly unity.

It appears to be well established that the acidity above referred to is due to boric acid; therefore, all carbonates transposable by this acid will evolve carbon dioxide with the simultaneous formation of sodium metaborate and sodium orthoborate when mixed with borax and glycerol.

The following equations present the facts in a most lucid manner:

(1) $2C_3H_5(OH)_3 + Na_2B_4O_7 = 2C_3H_5(OH)_3 + NaBO_2 + 3H_2O$.

(2) $2C_3H_5(OH)_3 + Na_2B_4O_7 + 3H_2O = 2C_3H_5(OH)_3 + 2H_3BO_3 + 2NaBO_2$.

(3) $C_3H_5BO_3 + 3H_2O = C_3H_5(O_3H)_3 + H_2 = 2C_3BO_3$.

(4) $3Na_2CO_3 + 2H_3BO_3 = 2Na_3BO_3 + 3CO_2 + 3H_2O$.

The first equation represents the reaction when water is absent, that which is formed being expelled by heat; the second, when water is present; the third the action of water on boroglycerol; and the last simply the action of boric acid

on an alkaline carbonate. When calcined sodium carbonate is fused with boric acid ordinary borax is produced.

Boric acid may replace successively the hydroxyl groups of polyhydric alcohols forming mono-, di-, tri- and poly- products, therefore, we may have simultaneously formed one or more products of transformation.

Glycerol here evidently plays the part of a catalytic, as sulphuric acid does in the formation of ether from alcohol. Thus alcohol is not converted into ether and water by boiling alone, but is so converted by boiling with sulphuric acid. The catalytic function of polyhydric alcohols is very clearly typified in the action of glycerol on borax. The quantity of glycerol is found to have neither increased nor decreased, but has, nevertheless, taken part in the several reactions, which would not have resulted but for the presence of glycerol or some other polyhydric alcohol, or of an aldehyde.

Catalysis has been of no small service in advancing stereometric chemistry through the agency of micro-organisms so admirably adapted for mesotomising various asymmetric carbon compounds, as the amylic alcohols, propylene glycol, mandelic acid, glyceric acid and many others through the agency of organized ferments. Among these, *Penicillium glauca* and *Bacterium termo* have been of especial service. Unfortunately we do not possess, in the inorganic field, an invaluable polariscope, which will reveal to us at a glance the ultimate transformations of a body under given conditions.

LABORATORY SMITH, KLINE AND FRENCH CO., 306 CHERRY STREET, PHILADELPHIA.

BOOK NOTICES.

Helical Gears: a practical treatise. By a foreman pattern-maker. New York: Macmillan & Co. 1894. Price, $2.00.

The author of this book elaborates in detail the method of making the patterns of helical gear wheels, and of the tooth blocks to be used in gear-moulding machines, and gives many valuable practical hints.

The enumerated advantages of helical gears can, however, properly be claimed only if the teeth are accurately divided and correctly formed. But

inasmuch as gear wheels with cast teeth are far from accurate, the claim of superiority should accordingly be qualified, especially since by reason of the vastly greater difficulty of making them, cast helical gears are, as a rule, less accurate than ordinary gear wheels. But as experience indicates that in some instances helical gears, when carefully made, give better results than others, the book will be a valuable guide for those who are in the position of having to make the patterns. H. B.

Standard Arithmetic. By William J. Milne. New York: American Book Company. 1893. 12mo. Price, 65 cents.

In this book the fundamental operations and principal commercial applications of arithmetic are clearly set forth.

We would call attention to the definitions of the terms unit and number, which, as they stand, are manifestly incomplete. If scientific definitions of these terms are too difficult for the pupil to understand when he begins the book, rather give him no definitions at all, but defer them until a more advanced part of the work.

This criticism does not apply to this book alone; it applies equally to a large number; in fact, to most of the books on elementary arithmetic in use in this country. But one looks to the new books to remove these old objections.

The work contains a large number of well-selected examples, designed, as the author states in his preface, to secure skill in calculation, and comprehension of methods.

On the whole, it compares favorably with the works on arithmetic in common use. E. A. P.

American Mental Arithmetic. By Prof. M. A. Bailey. New York: American Book Company. 1893. 12mo. Price, 35 cents.

We have in this book an excellent drill book in the subjects usually included in a work on elementary arithmetic. The use of parallel columns, one containing statements and the other illustrations of them, is to be commended, since it associates as closely as possible the principles enunciated with explanations of them, still preserving continuity of statement.

We are pleased to see so large a space devoted to the metric system, as the importance of an early knowledge of it cannot be overestimated. In this connection, however, we desire to point out an error in the definition of the meter. It has nothing to do with the dimensions of the earth, but is simply the length of a certain bar of platinum at 0° Centigrade.

It is to be regretted that the author, in accord with recent tendencies in teaching arithmetic, has dismissed the subject of proportion in a single page. The author is to be congratulated for introducing a few problems involving the notion of density. A great deal of arithmetic, as well as a great deal of elementary physics, can be well taught by properly selected examples of this kind. E. A. P.